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April 16. 1993

RISØ
PARTICIPATION IN:

THE
MADONA
EXPERIMENTS:

(Meteorology and Diffusion Over Non-uniform Areas)

UK PORTON DOWN

7-25 SEP. 1992.

1. & 2. Interim Data and Analysis Report on:

HIGH-RESOLUTION IN-PLUME CONCENTRATION FLUCTUATIONS MEASUREMENTS USING LIDAR REMOTE SENSING TECHNIQUE

by

Principal Investigator:
Torben Mikkelsen, Ph.D

Associate Investigators:
Hans E. Jørgensen , Søren Thykier-Nielsen, Søren W. Lund and
Josep Moreno Santabarbara

Department of Meteorology and Wind Energy
Risø National Laboratory, DK-4000 Roskilde, Denmark

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Contents

1 Introduction

1.1 Summary

The Department of Meteorology and Wind Energy at the Risø National Laboratory in Denmark participated and supported:

The MADONA:

(Meteorological And Diffusion Over Non-uniform Area)

Trials

Conducted at

Porton Down, Salisbury

CBDE-UK; Sep. 7 - 25 1992.

Risø contributed with the following activities:

1) Continuous smoke dissemination from ground level sources.

2) High-resolution protile-measurements of instantaneous plume dispersion and concentration fluctuations by use of a mini-LIDAR system. (Remote sensing)

3) Micro-meteorological measurements of wind and temperature quantities from two 7 meter tall met-towers equipped with 20 Hz sonic anemometers for characterization of the mean and turbulent state of the boundary layer.

4) Mean wind and diffusion modelling using our real-time diagnostic models LINCOM/RIMPUFF.

1.2 Objectives

The scientific objective for our participation in MADONA was to investigate fundamental questions regarding the statistical properties of the instantaneous concentration fluctuations in smoke plumes and puffs. The joint-venture Porton Down experiments, with international participation and support facilitated this objective. Modelling objectives included investigation and experimental evaluation of flow and diffusion modelling based on our LINCOM/RIMPUFF real-time codes.

With our high-resolution mini-lidar system, sequential measurements (1/3 Hz) were obtained of the instantaneous cross wind concentration profiles at fixed down wind distances from the source. The source consisted of ground level continuous smoke releases and elevated smoke puff releases.

The cross wind concentration profiles were measured with an effective spatial resolution of 1.5 meter.

From the conducted puff and plume diffusion experiments, we have by post-processing and data reduction obtained important concentration fluctuation statistics including:

> Mean- and variance profiles, intermittency profiles, probability distribution functions, dispersion parameters (including instantaneous puff width). In addition we distinguish statistics obtained in a fixed frame (absolute diffusion), and center-of-mass frame (relative diffusion).

Derived statistics (to be performed) include:

> Dispersion coefficients, and their dependence on sampling time (from instantaneous to length of experiments, typically 1-hour.)
>
> Two-particle distance-neighbor functions yielding information about the instantaneous spatial correlation function of in-plume fluctuations.
>
> Extreme statistics of exeedance of certain reference levels, and the (ensemble mean) duration of such exeedances.

Our Lidar based concentration fluctuation measurements were supported by our micro-meteorological observations from two tower mounted sonic anemometers, in addition to the joint mean wind and turbulence data gathered simultaneously by the participating groups at Porton Down.

1.3 Background:

Within the CEC Radiation Protection Research Programme for Nuclear Safety, Risø is commissioned to conduct reference smoke plume dispersion experiments, where we based on the mini-LIDAR facility are studying concentartion fluctuations for dispersion model evaluation and model uncertainty assessments. Also, we are conducting full scale reference and training experimental data for the CEC supported real-time decision support system RODOS, where atmospheric dispersion is a key element.

The layout and experimental set-up for the Porton Down MADONA experiments, including the many other participants, provided an unique opportunity to combine and jointly perform already scheduled uncertainty and evaluation experiments with the general objectives for MADONA.

Our entire scientific outcome from the smoke diffusion trial are consequently offered for inclusion in the MADONA data base, including the basic scientific analysis as described above. All raw and statistical analyzed data from our LIDAR and micro meteorological measurements are shared. The latter includes 10-min mean and turbulent scaling parameters such as variances, energies, shear stress and heat flux (Monin-Obukhov length).

1.4 Reporting:

This is a first interim data report describing the experimental setups, time periods and atmospheric conditions for the MADONA trials.

A final report, including the statistical analysis and interpretation of results will be available end of august 1993.

1.5 Acknowledgements:

Risø obtained additional financial support for expenses associated with moving our experimental facilities and personnel to Porton Down,UK.

Our participation in the MADONA trials were hereafter made possible by support from the CEC Radiation Protection Research Programme, DGXII, under contract No. BI7-0017-C, and by a grant from the US Army Research Branch, London, under contract No.DAJA45-92-M-0344. Mr. Ron Cionco at the U.S. Army Atmospheric Science Laboratory, White Sands, MN., USA and Mr. Jerry Comati at the US Army Research Branch, London, are gracefully acknowledged.

2 Technical describtion

2.1 Mean and turbulence measurements from two micro-meteorological masts:

Two 7 meter high meteorology mast were erected and instrumented at the Porton Down site near the Westerly source point, see Fig. II.1. (Porton Down landscape seen from South-West.)

The met-towers were each equipped with Kaijo Denki DAT 300 sonic anemometers in order to obtain both mean-profile and turbulence scaling parameters for the MADONA dispersion trials.

Appendix II.1: Contains directly measured mean and turbulence quantities, including:1) Mean Wind speed,2) Direction,3) Turbulent Kinetic Energy, 4) Stress, 5) Sensible Heatflux, 6) Monin-Obukhov Stability parameters and 7) Temperature statistics.

Appendix II.2 Comparison between 5 and 10 min averaged statistics for day: 23/9 192; sonic 1 and sonic 2.

The measurements were obtained from two acoustic three-dimensional sonic-anemometer/thermometers (Kaijo Denki type DAT-300), located at 7 meter level above the floor.

Running continuously during the entire experimental campaign, they provided us with real-time, on-line surface layer turbulence statistics of the most important scaling parameters for dispersion. By use of our PC-based on-line data acquisition system and associated computers, we measured and calculated (in real-time) the entire co-variance matrix of the fluctuating quantities u',v',w' and T' (by the correlation-method), and from here, the velocity and temperature intensities, the shear-stress and the sensible heat flux was deduced at 10-min intervals in real time. With the additional information of the inversion height from rawin-sonde balloons (not provided by Risø), the sonic anemometer data enables us to calculate the very important scaling parameter for convective conditions: w_*.

Our sonic-based on-line "turbulence monitoring-system" provides the experimenters and the project-manager with real-time measurements of the atmospheric stability and turbulence state at Porton Down, concurrently with each diffusion test and provided also direct measurements of the variances and fluxes requested for the subsequent model evaluation study.

The Risø Sonic-DAS-system was put in continuous operation throughout the whole experimental period.Our directly measured, 10-min averaged quantities included:<u'u'>, <u'v'>, <u'w'>, <u'T'>, <v'v'>, <v'w'>, <v'T'>, <w'w'>,<w'T'>, <T'T'>, in addition to the mean wind speed and mean temperature.

The accuracy of the sonic anemometer/thermometer type DAT 300 is, according to the manufacturer (Kaijo Denki Co.): +/- 1% on measured velocity and temperature signals, the resolution is 0.5 cm/s and 0.025 K, respectively. It measures all signals 20 times per second and has a 10 Hz low-pass output filter. For measurements taken 7 meter above the ground, this instrument will provide very adequate resolution of the turbulent signals, both with respect to spatial and temporal resolution: The on-line data acquisition system (DAC_SYS) point-samples the four signals U,V,W and T at a rate of 10 Hz, and subsequently calculates the co-variance matrix after each 10-min period based on the corresponding 6000 readings of each signal.

The directly measured time series (consisting of four times 6000 measurements each per 10-min period) are also stored for subsequent spectral analysis.

Data-, both mean and of the turbulence quantities, have already been processed, stored and backed-up as 10-min average quantities. Additional to visual inspection of raw time series, more objective quality assurance in accordance with Højstrup, 1993 will be performed on central data periods.

2.2 High-resolution Time-series and Spectral Analysis:

Additional spectral analysis can at request be performed on 10-min average meteorological quantities. For each of the scheduled diffusion tests, the following is available on request:

1. Time series plots of high-resolution (10 Hz) wind and temperature signals from the sonic anemometer.

2. Time series of short-time averaged (1-min running mean) quantities of wind speed, direction, turbulence level, shear stress and heat flux.

3. Spectral analysis of the three wind (u',v',w') and temperature (T') signals.

This information is of importance in a subsequent modelling evaluation. in particular for:

I Gaining insight into the fine scale temporal evaluation of the boundary flow and turbulence in the valley during each diffusion test.

II gaining insight into which turbulent scales are of importance and most energetic, and consequently responsible for the exchange and diffusion processes, and

III Providing detailed turbulence measurements at the source point for use in the subsequently planned model simulation of the experiments.

We provide on request, for each of the successfully performed diffusion tests:

re i. 10-Hz digitized raw data of U,V,W and T on PC-diskette.

re ii. Time series plots of sonic data and of the correspond- ding 1-min running mean turbulence quantities.

re iii. Plots of the three velocity spectra and the temperature spectrum from 0.001 to 5 Hz

3 LIDAR-measurements of surface-released smoke plumes:

The Risø National Laboratory operates a mini-LIDAR system for determination of instantaneous concentration profiles inside dispersing aerosol-plumes.

The system yields high spatial and temporal resolution measurements of in-plume concentration fluctuations, from which important and basic scientific plume dispersion characteristics can be inferred.

For the MADONA trials, we provided a powerful and sturdy artificial smoke generator, which produced ground-level releases of smoke plumes or elongated puffs.

The smoke consisted of non-toxic white plume of sub-micron aerosols. The aerosols were conglomerated SiO_2 and NH_4OH that is detectable by our 1.064 μ lidar system. In this way, measurements of the cross-wind near-ground concentration profiles were obtained at various distances downwind.

During evenings and nights with stable atmospheric conditions, the lidar system can pick up the smoke plume concentrations out to several kilometers from the source point.

At Porton Down, the mini-LIDAR system measured instantaneous "snapshots" every 3. or 5. second of the aerosol back-scatter cross-section.

Table III.1: **Contains information of lidar positions and measurement periods obtained at the MADONA trials.**

Includes also drawings of source and lidar positions for the total of 23 experiments.

Fig. III.1: LIDAR scanned mean concentrations from MADONA experiment No. 22f (1 hour 22 min continuous release).

Fig. III.2a-d: From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in fixed frame (meander included).

Fig. III.3a-d: From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in moving frame (meander removed).

The measurements related to the number of aerosols in the small measurement volume, which is a "cigar-shaped" cylinder of approx. 1 meter in diameter and approx. 1.5 meter long.

Extensive data-processing of the raw lidar-signals is in progress in order to produce accurate and quality-assured cross-wind aerosol concentration profiles. In return, we obtain from each experiment, not only the mean concentration profile, but also a measure of the natural fluctuation and inherent uncertainty associated with dispersion. This is of importance for subsequent model evaluation studies.

During madona, we obtained both stable, neutral and unstable experiments based on both plume and puff releases. The release rate of the aerosol generator was kept constant during individual experiments.

Our contribution to the MADONA data base contains, for each experiment:

1) Time series of cross-wind profiles
2) Plots of mean cross-wind concentration
3) Plots of fluctuating (rms)
4) Plots of in-plume intermittency
5) Measurements of the entire measured concentration pdf (probability density distribution) from which, for instance, different exceedance statistics and high-level exposure events can be inferred.

The posterior data processing, reduction and analysis of our Lidar-activity is rather involved, and will require between 6 and 12 month of data preparation and analysis following the experiments to finalize.

4 Modelling

4.1 Mean-flow modelling directions:

In connection with our on-going activities with the CEC-RODOS activities for real-time on-line decision support, we additionally setup our modelling system LINCOM/RIMPUFF at the MADONA site:

For mean-flow wind field calculations at the Porton Down experimental area , we have setup our fast PC-version of LINCOM to calculate winds over the experiment site at various heights and for different synoptic wind directions. LINCOM is a non-hydrostatic spectral, neutral wind code, cf. Santabarbara (1993).

LINCOM is setup to run based on the measured tower winds and as such, it is suitable as driver for dispersion studies over complex terrain. Alternatively, the model can run on a single wind speed and direction as input, if the dominating winds are driven by synoptic forces.

Our studies include comparison of measured tower winds with model results based on single inputs, the MADONA study with several wind observations are unique for this model/data intercomparison.

At present this flow model is under development in order to incorporate the effect of thermally driven forcing such as night-time drainage flows and day-time up-valley breezes. Since this model is a central as a "driver" for our puff-dispersion model RIMPUFF in complex terrain, it is worthwhile to test its applicability for the Porton Down terrain in question,- and possibly even use the obtained results from these experiments in order to evaluate our efforts regarding improving the model to include the effects of thermal forcing.

4.2 Combined Mean-wind and Dispersion Models for Real-time Plume Dispersion Assessment over undulating Terrain:

Our dispersion modelling work is centered about a Lagrangian Mesoscale Puff-diffusion model (RIMPUFF), which over the years has obtained acknowledgement and use internationally, for instance in the UFOMOD and the COSYME consequence assessment systems available in public domain by the CEC. For dispersion calculations over complex terrain, the PC-based RIMPUFF model is presently twinned with the non-hydrostatic mean flow model LINCOM, which is based on the Navier-Stokes equations for motion, including mass, momentum and heat conservation. The combination of the flow and diffusion model results in an extremely fast computer code, which advantageously can be tested and evaluated in real time with experimental data from the present diffusion experiments.
A modelling effort based on selected MADONA diffusion trials is consequently in progress.

Appendix IV: **Contains the first preliminary model results of wind and diffusion calculations from the MADONA trials:** Sep 17,release time 11:10 - 16:10.

Fig. IV.1: Shows LINCOM output of hourly consecutive wind field calculations based on tower data inputs.

Fig. IV.2: Shows detailed stream line plot of one of these wind fields, including tower wind data???

Fig. IV.3: Shows instantaneous plume positions at ten minute intervals and also total integrated concentration (dose).

Fig. IV.4: Porton Down terrain vertical magnified x 20 seen from south-west

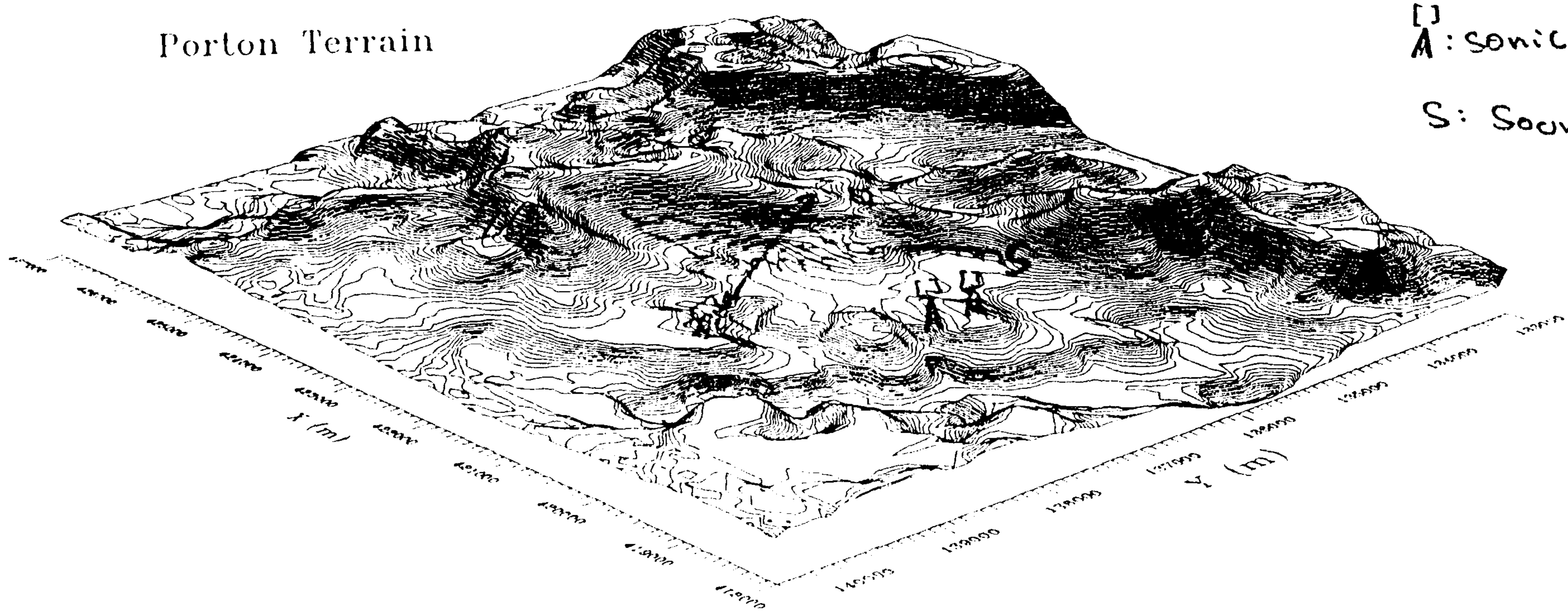
Fig. IV.5: Example of tower data representation for Lincom inputs.

Fig. IV.6: Example of Lincom grid wind field (10 meters height) 300 meter horizontal resolution

Fig. IV.7: As Fig. IV.6, 100 m horizontal resolution.

Fig. IV.8: Example of stream line wind field from neutral LINCOM (10 meters height) at Porton Down terrain.

Fig. II.1



APPENDIX II.1

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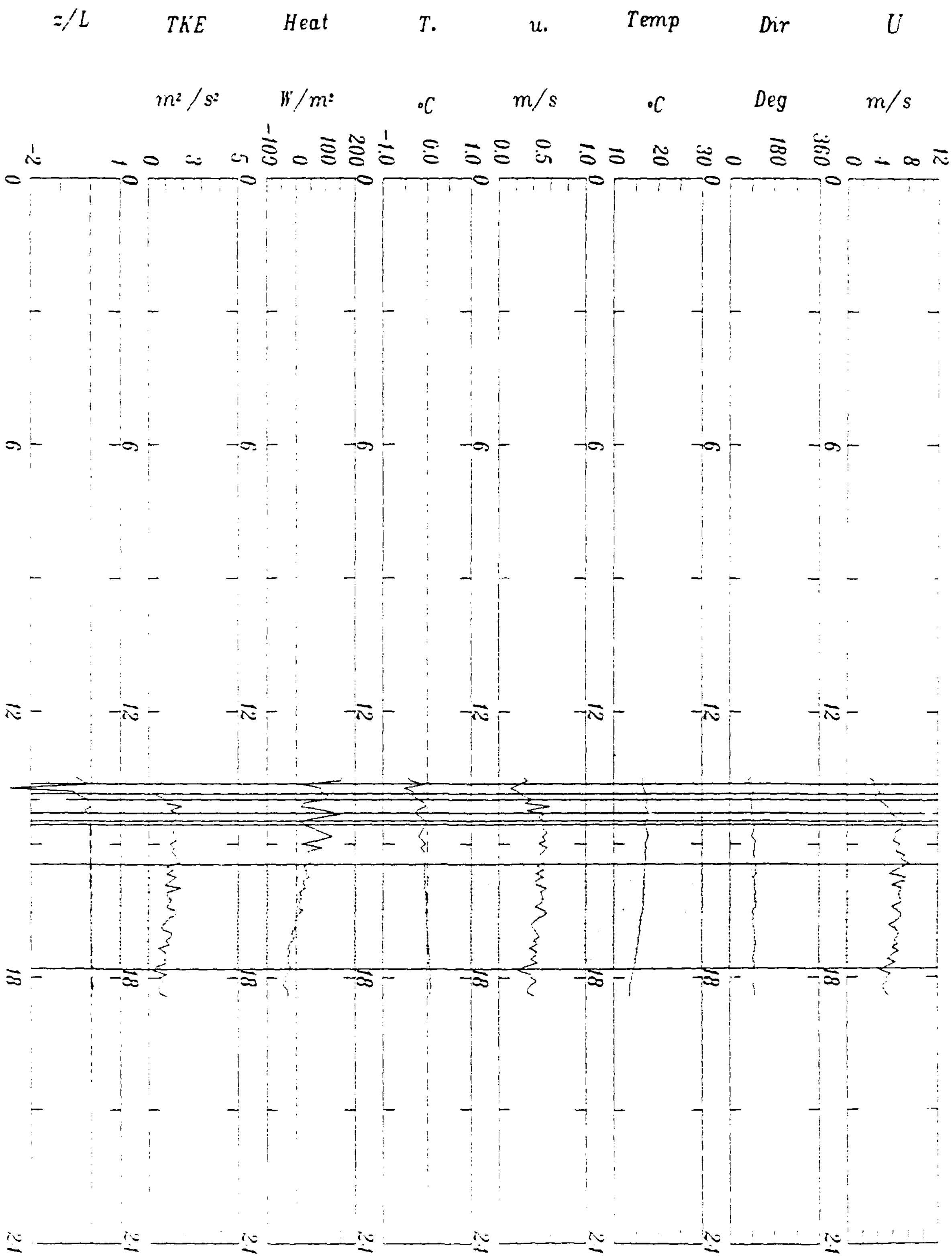

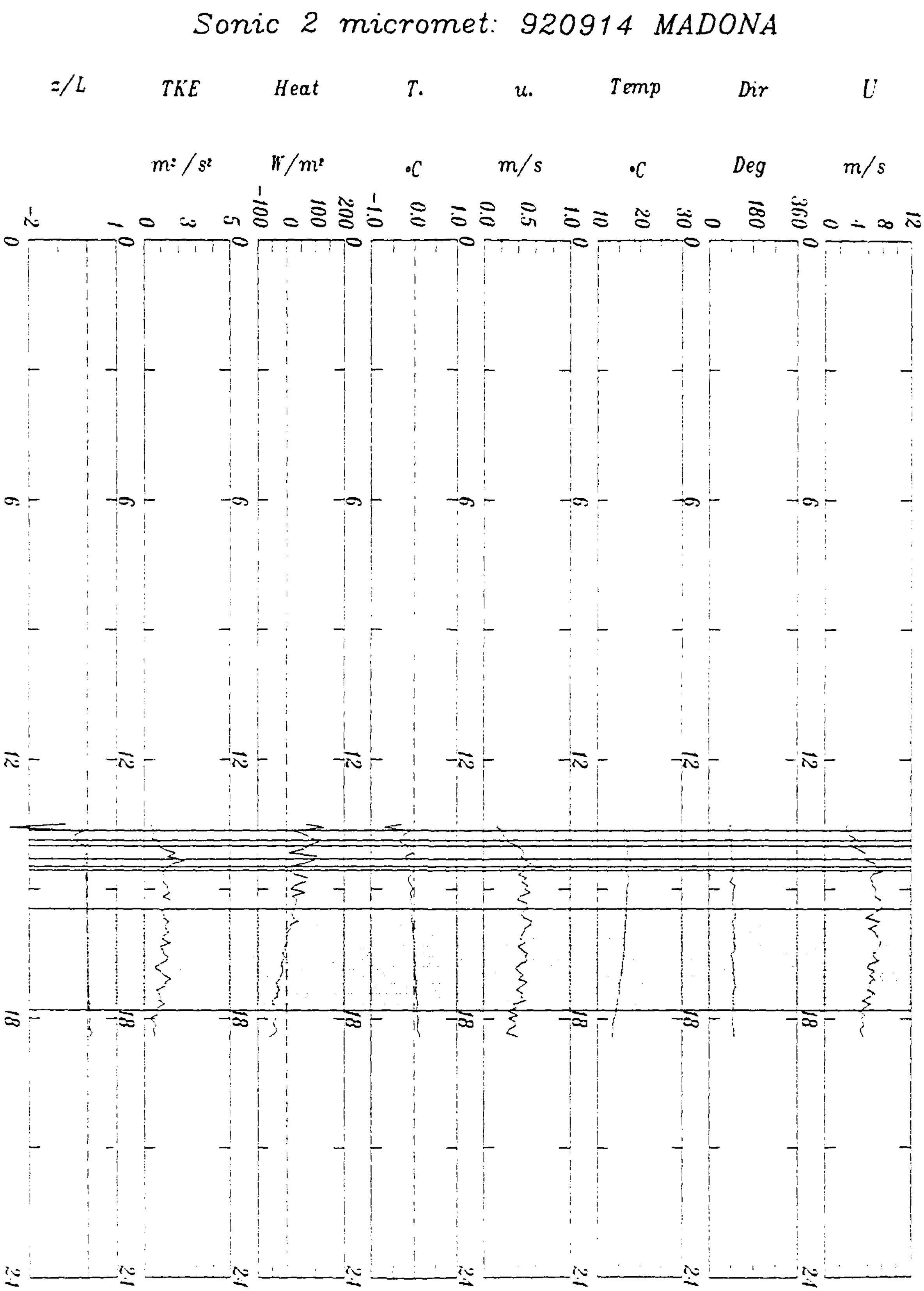

Sonic 2 micromet: 920914 MADONA
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-1.0
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1.0
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24

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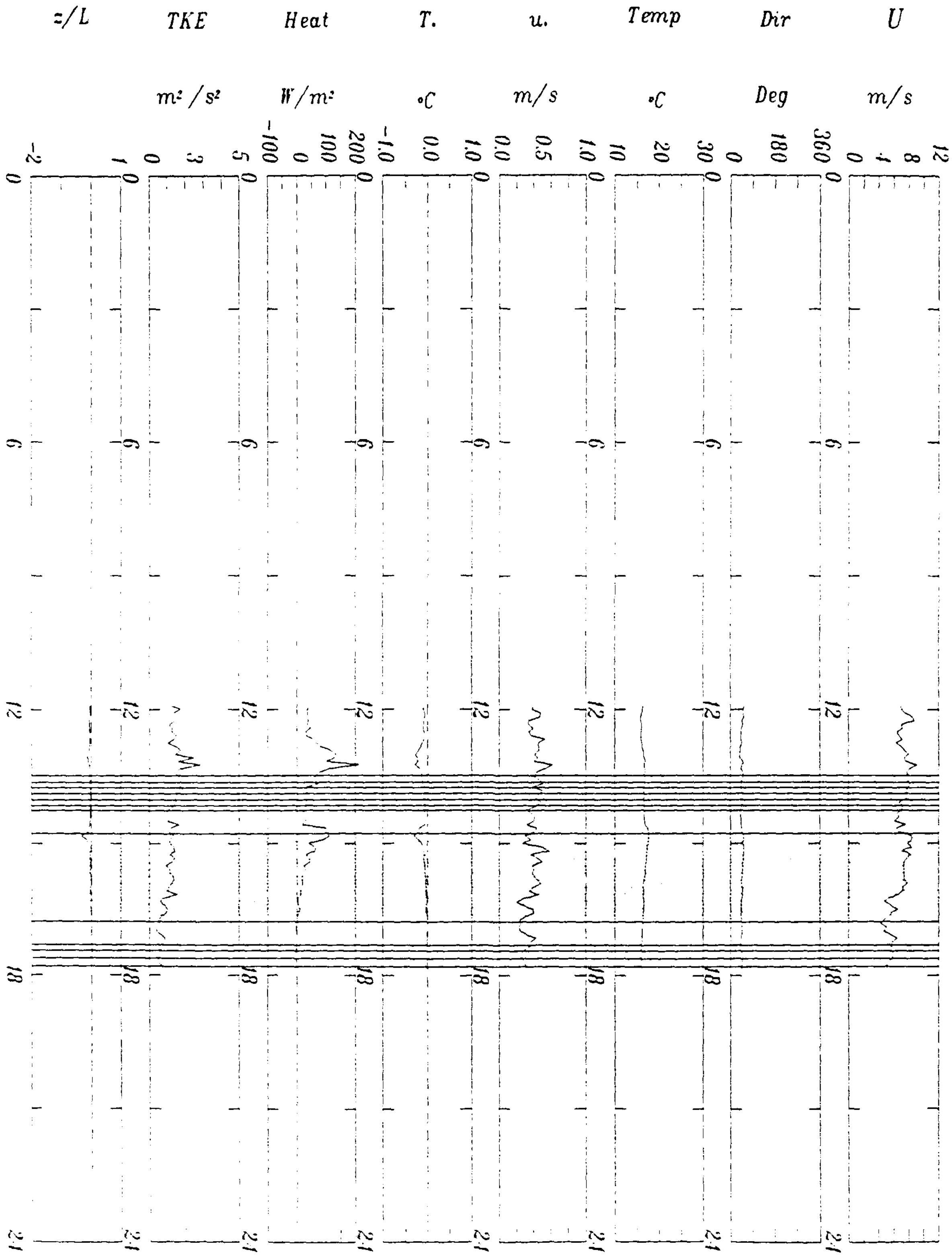

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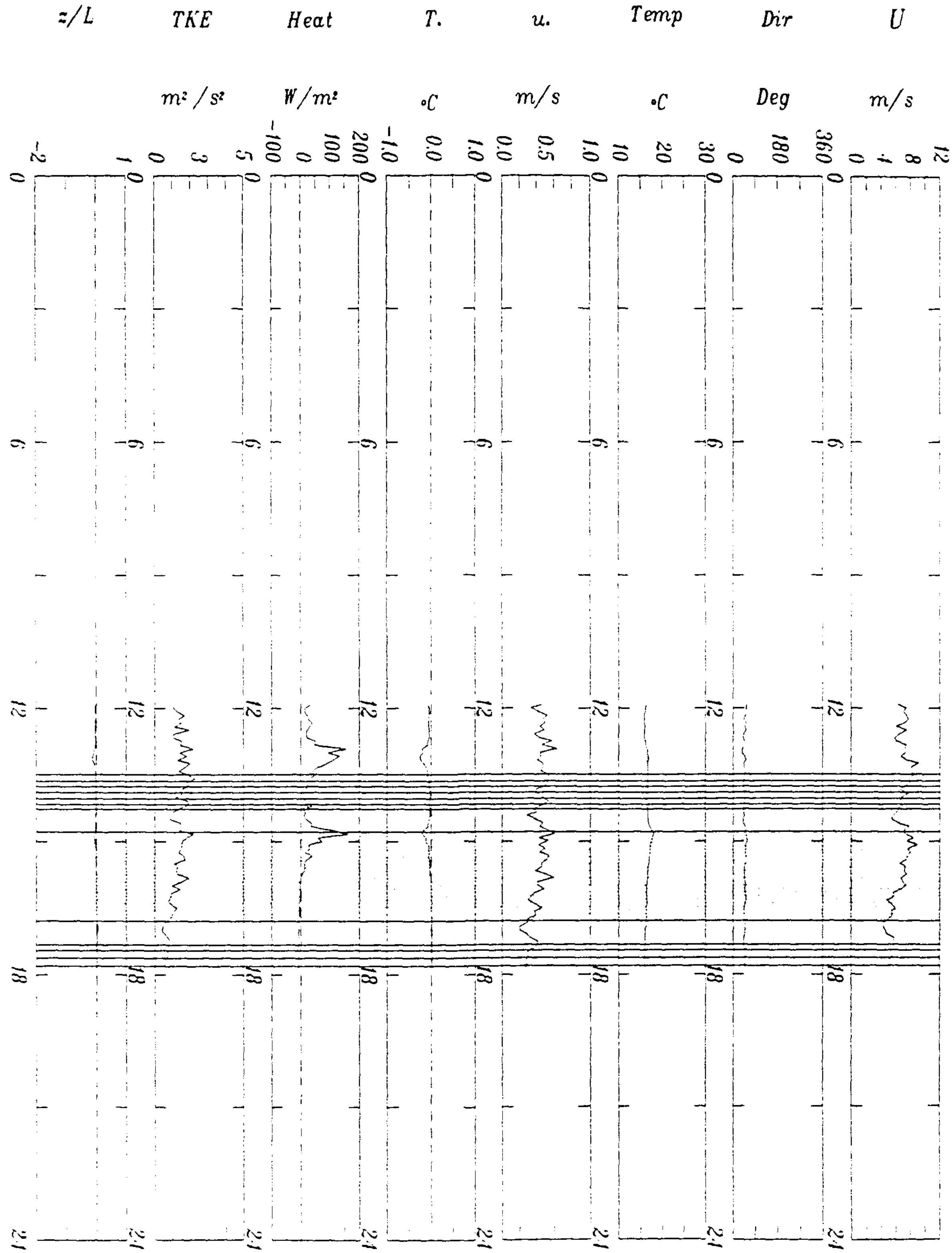

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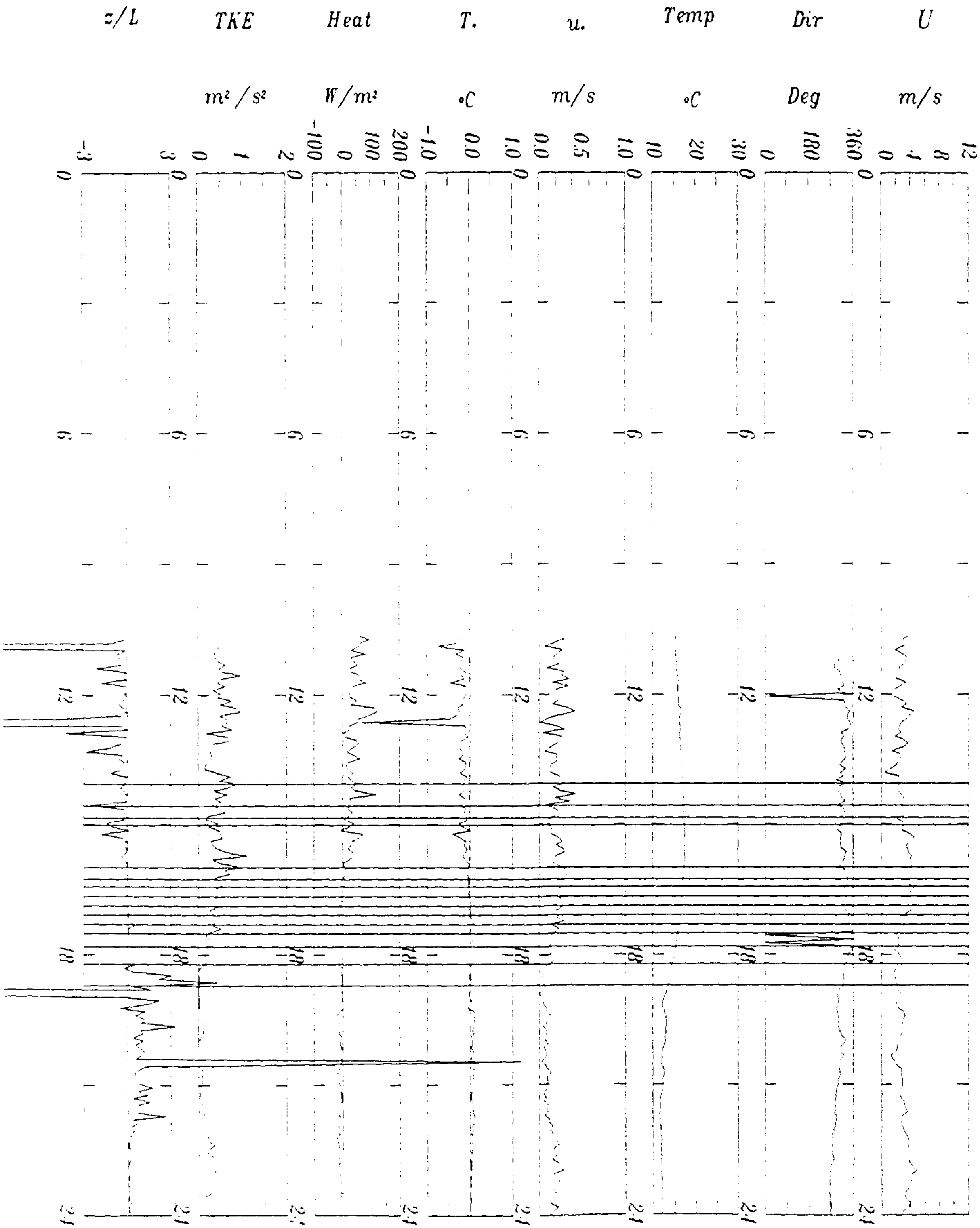

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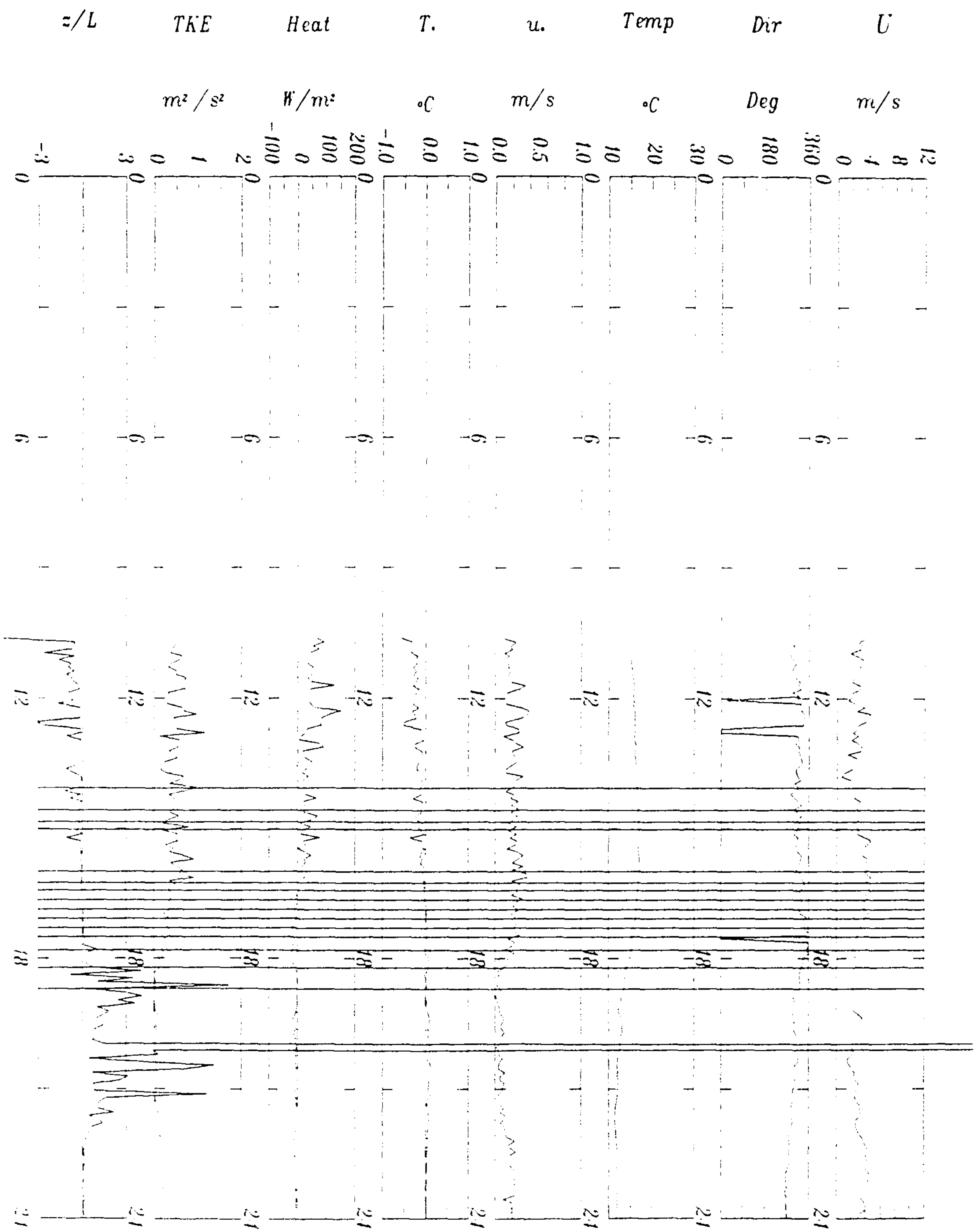

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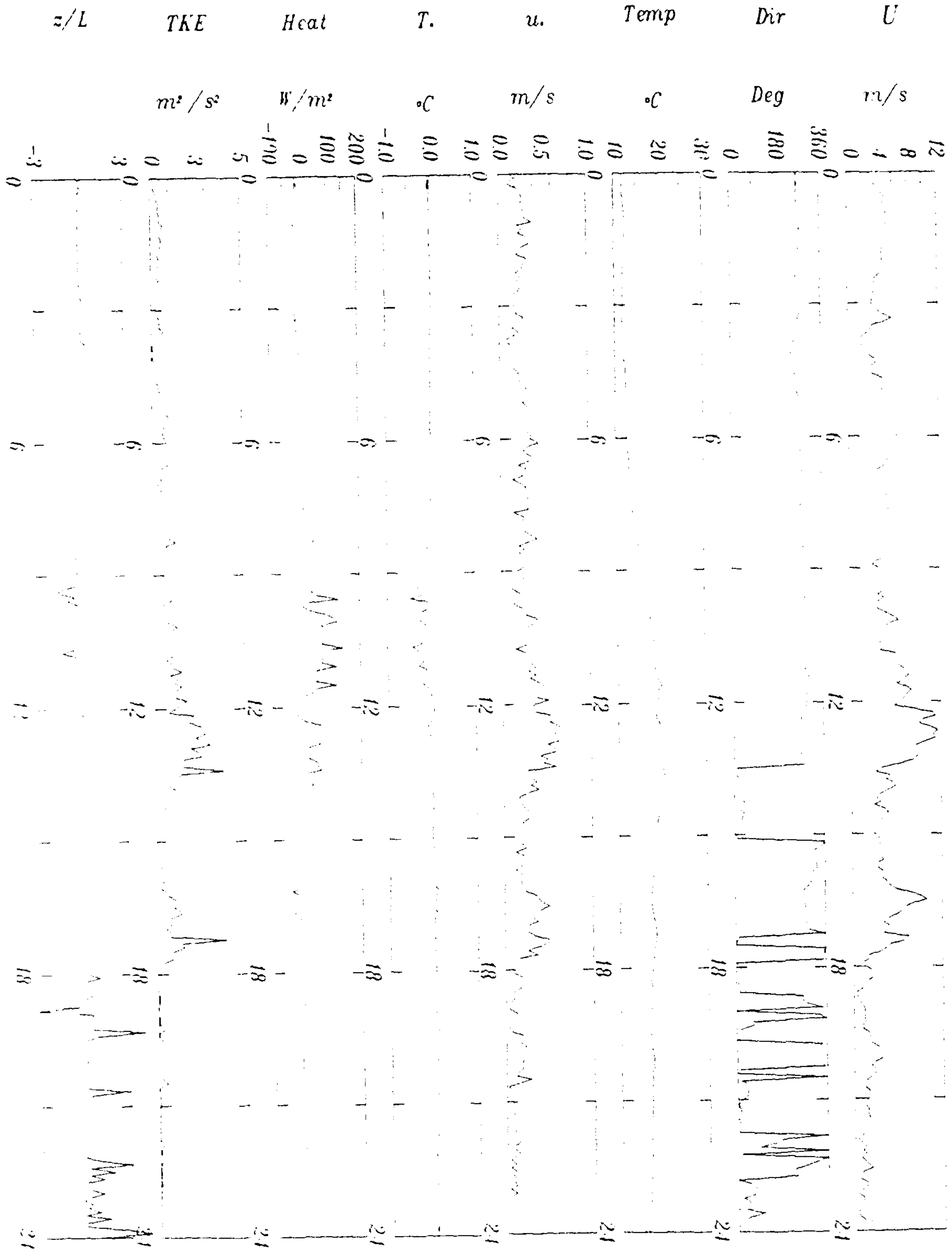

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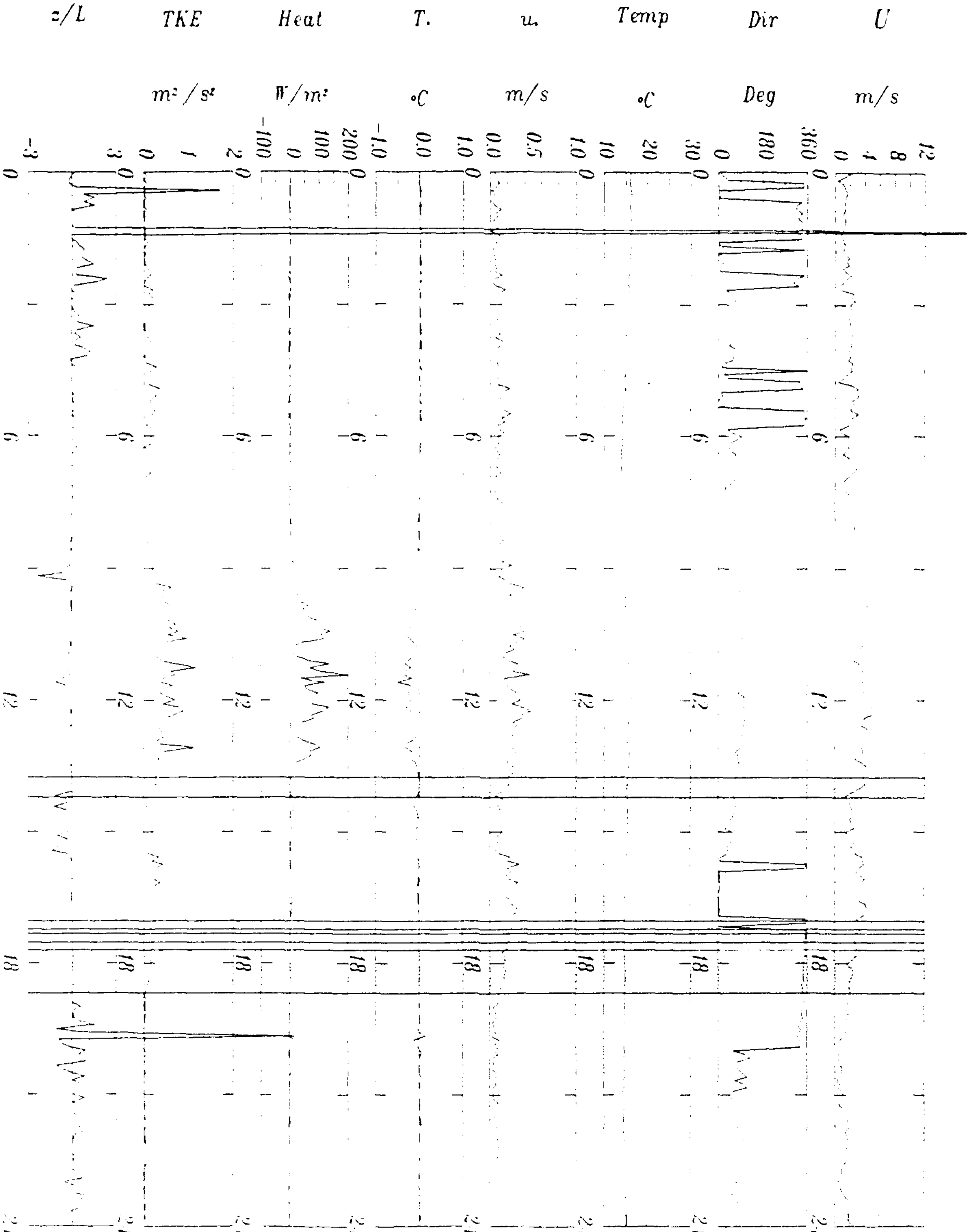

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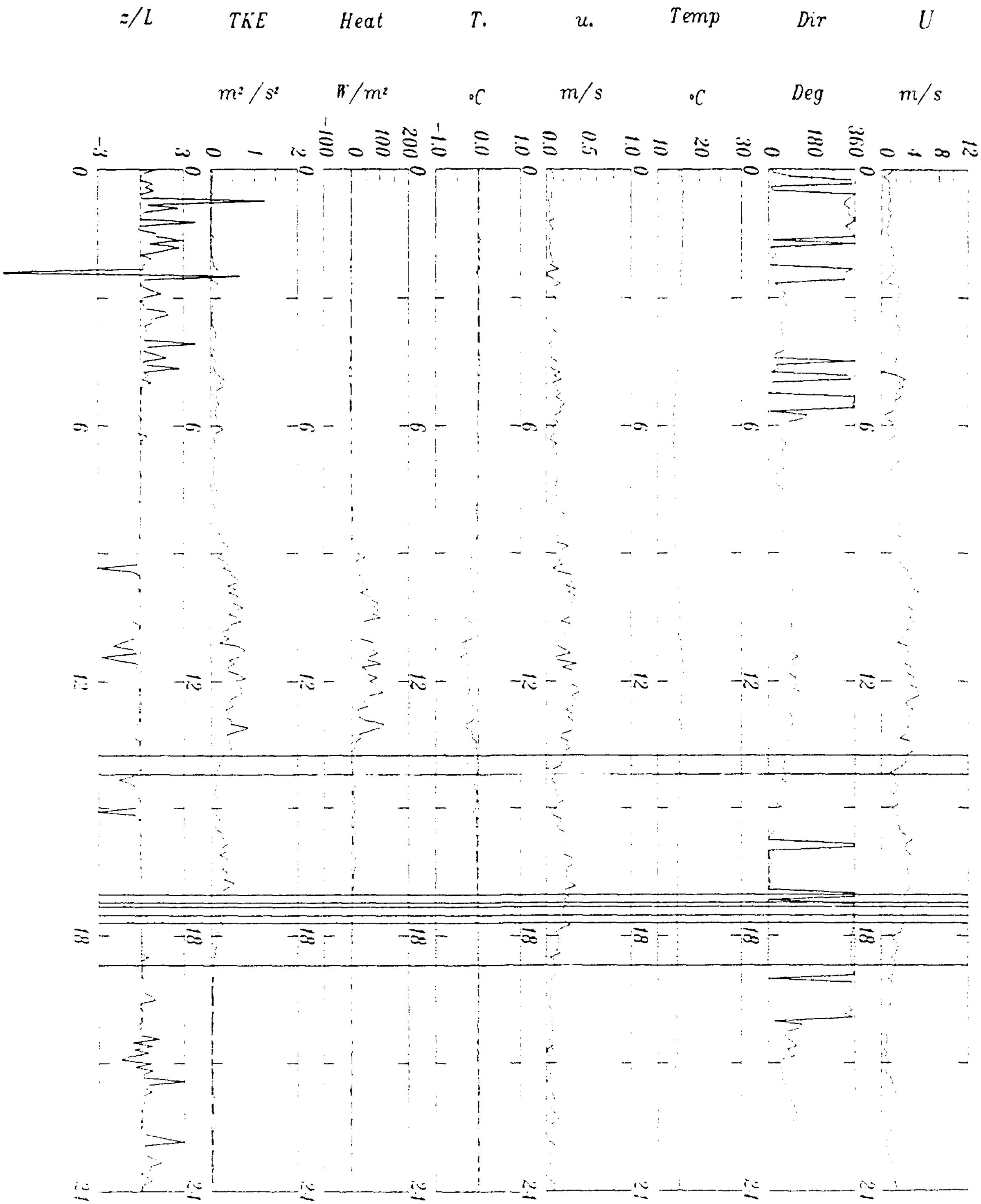

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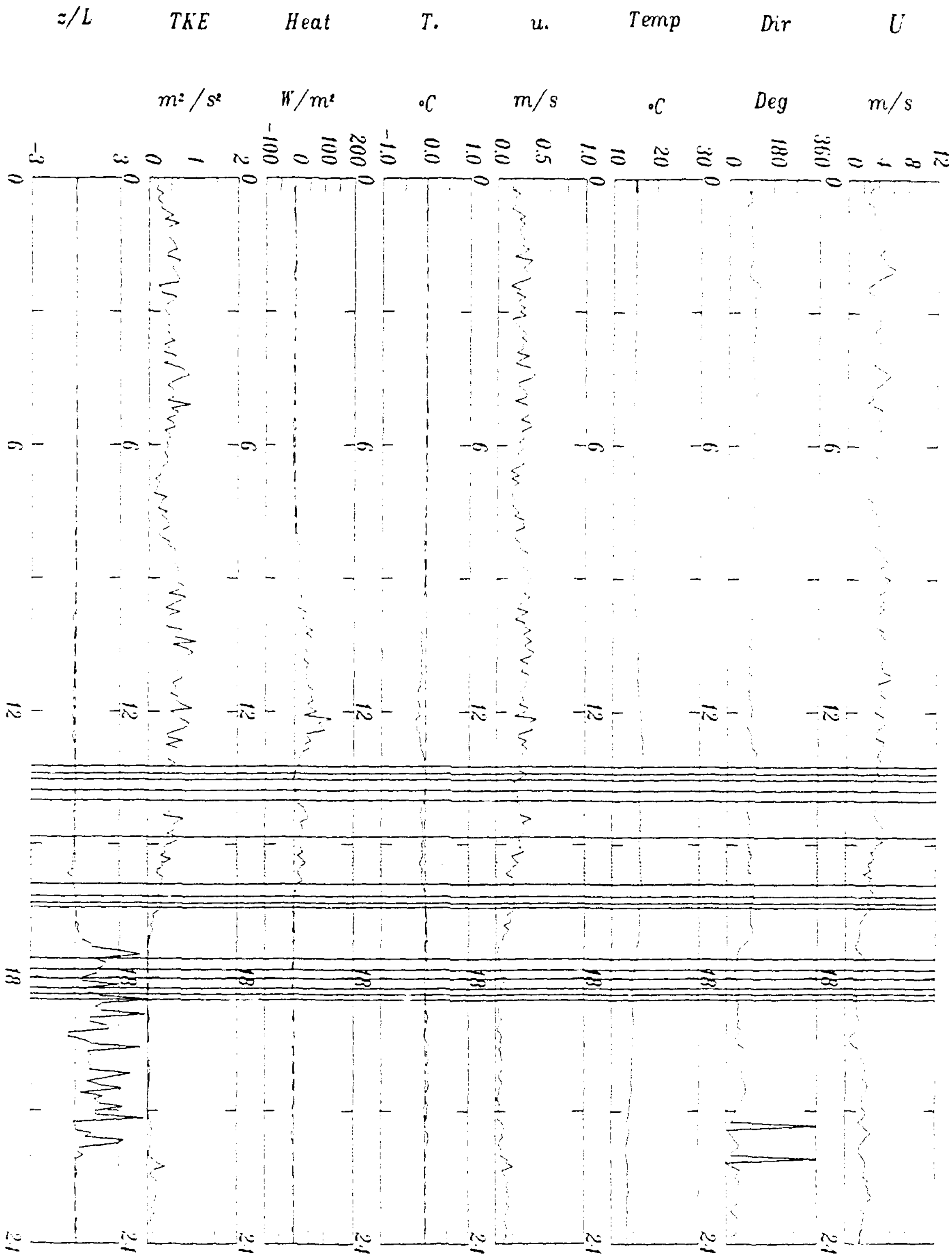

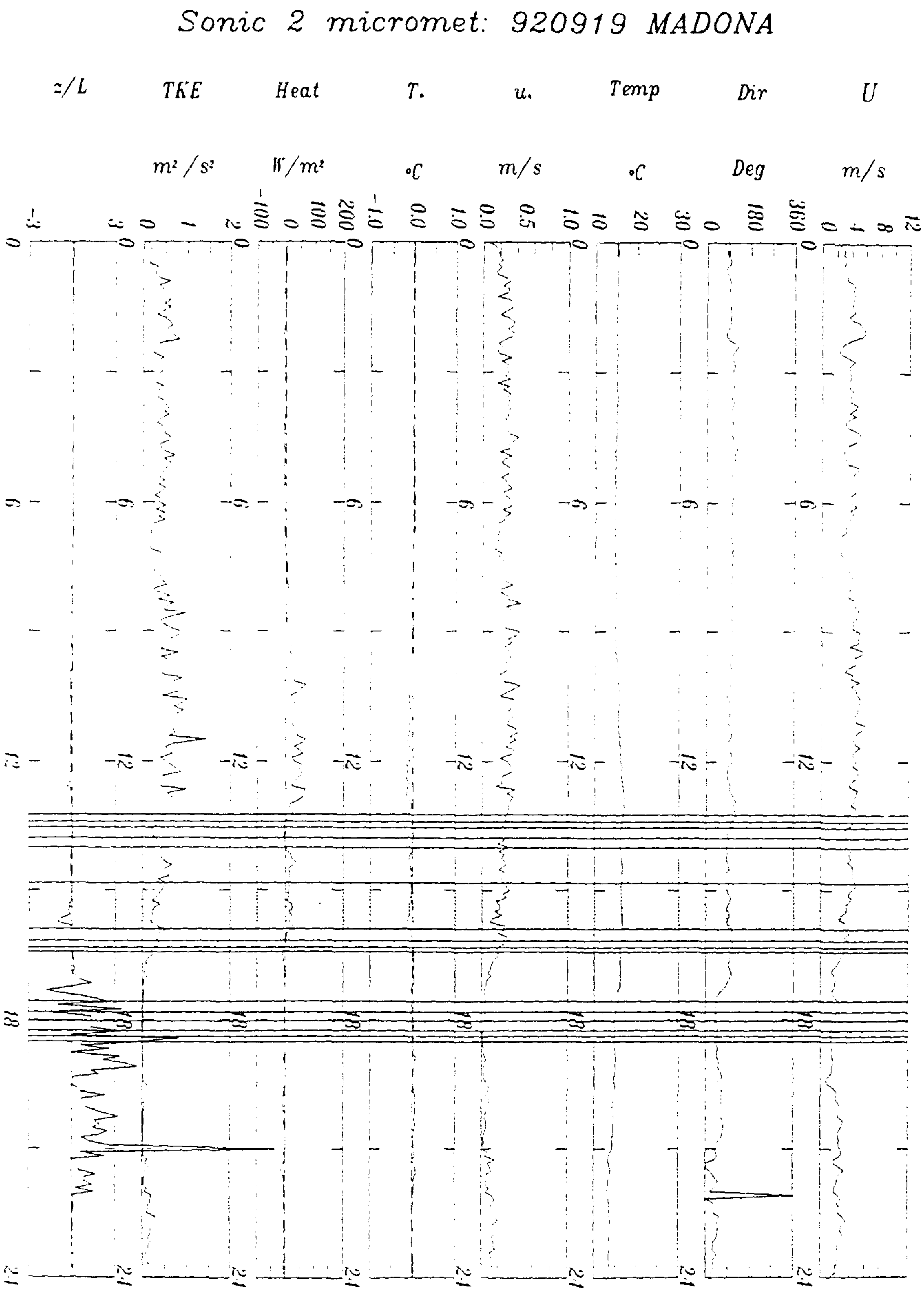
Sonic 2 micromet: 920919 MADONA
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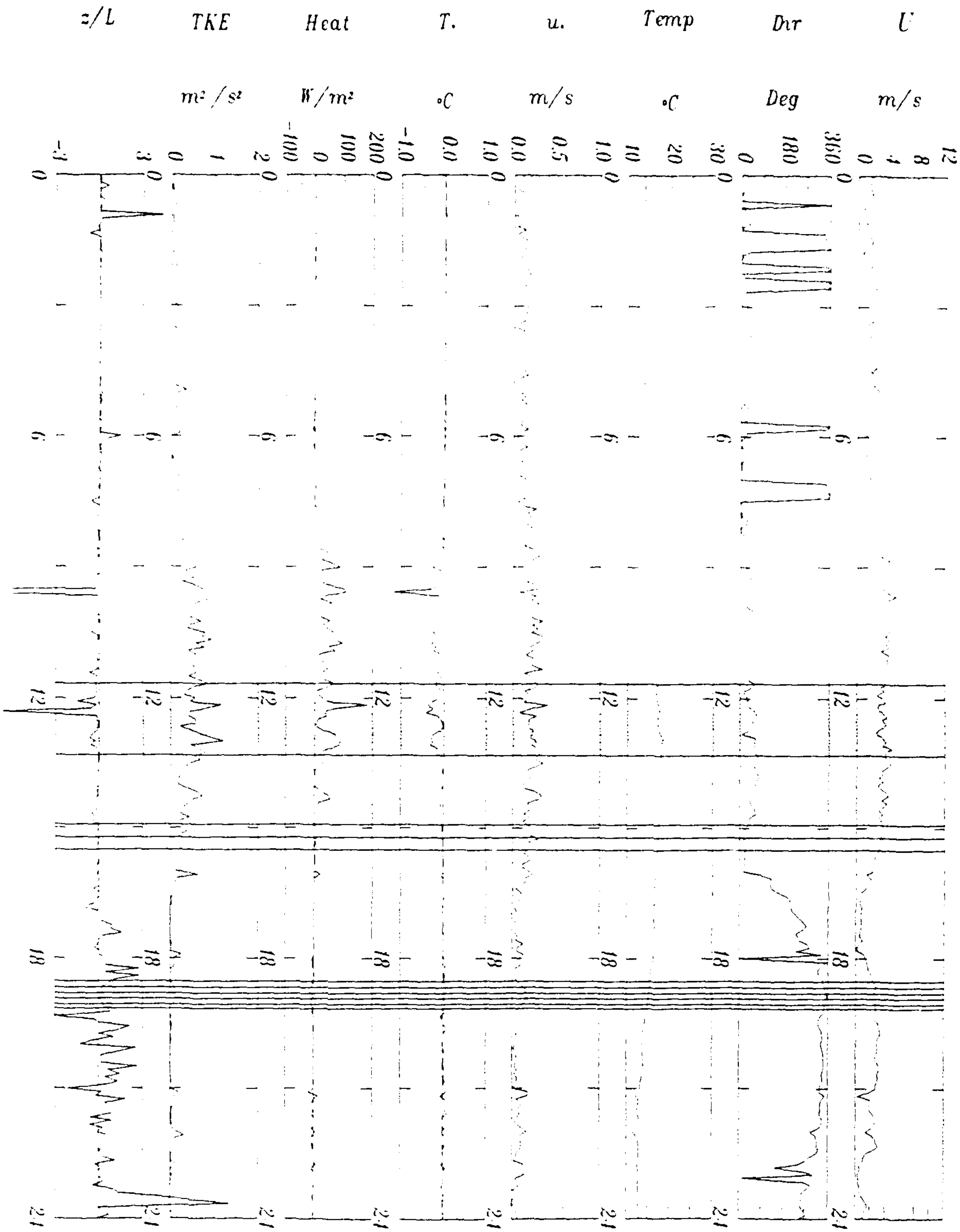

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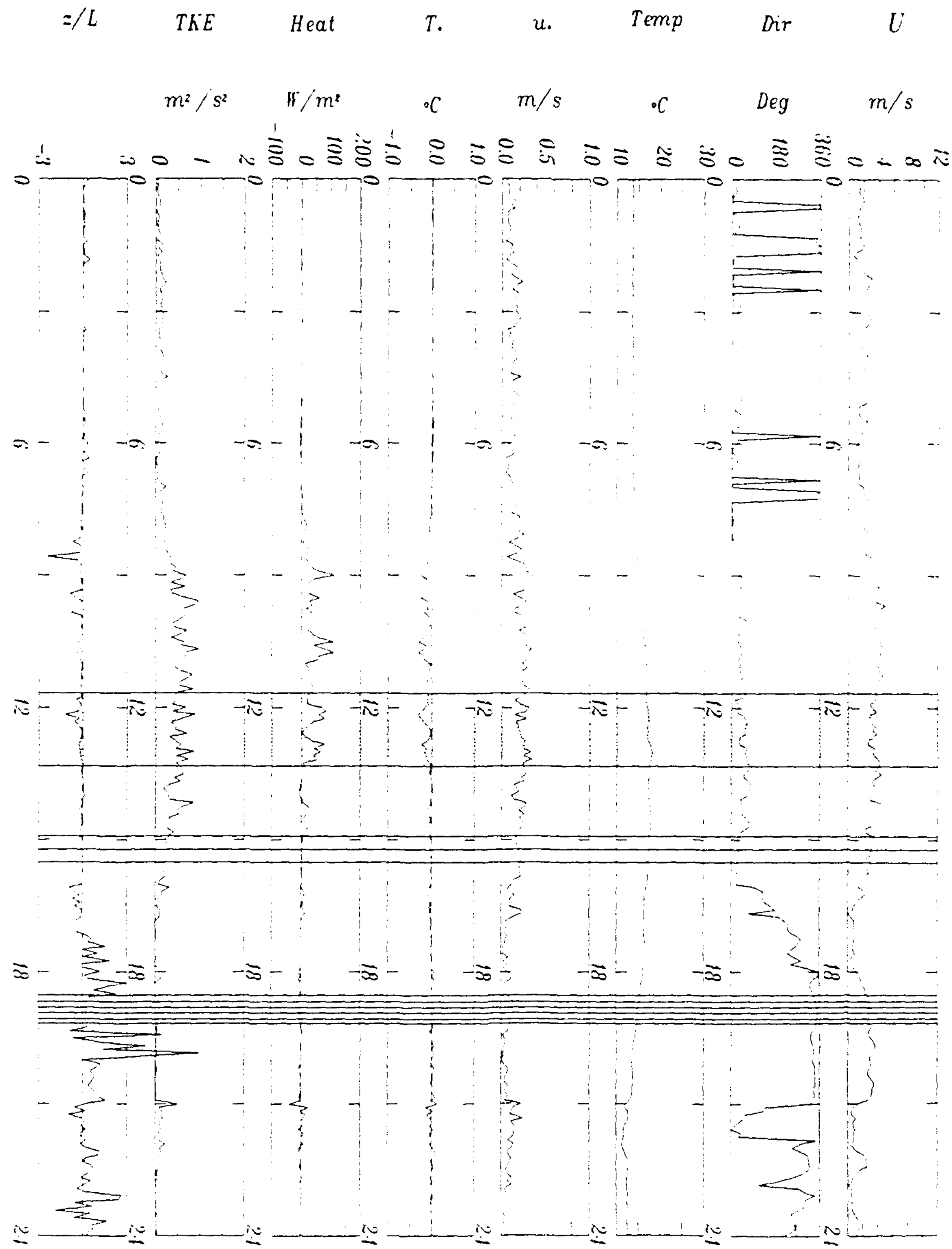

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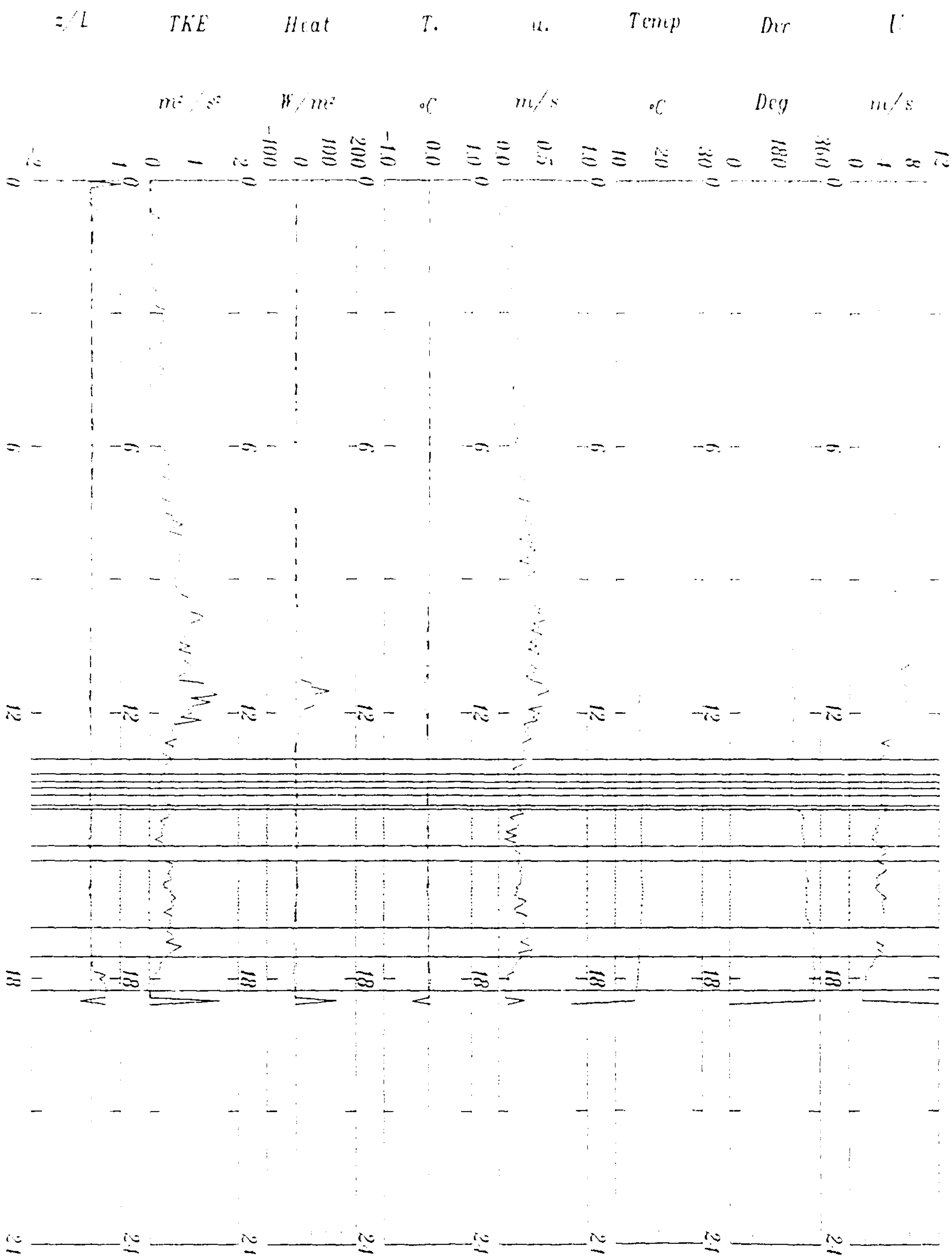

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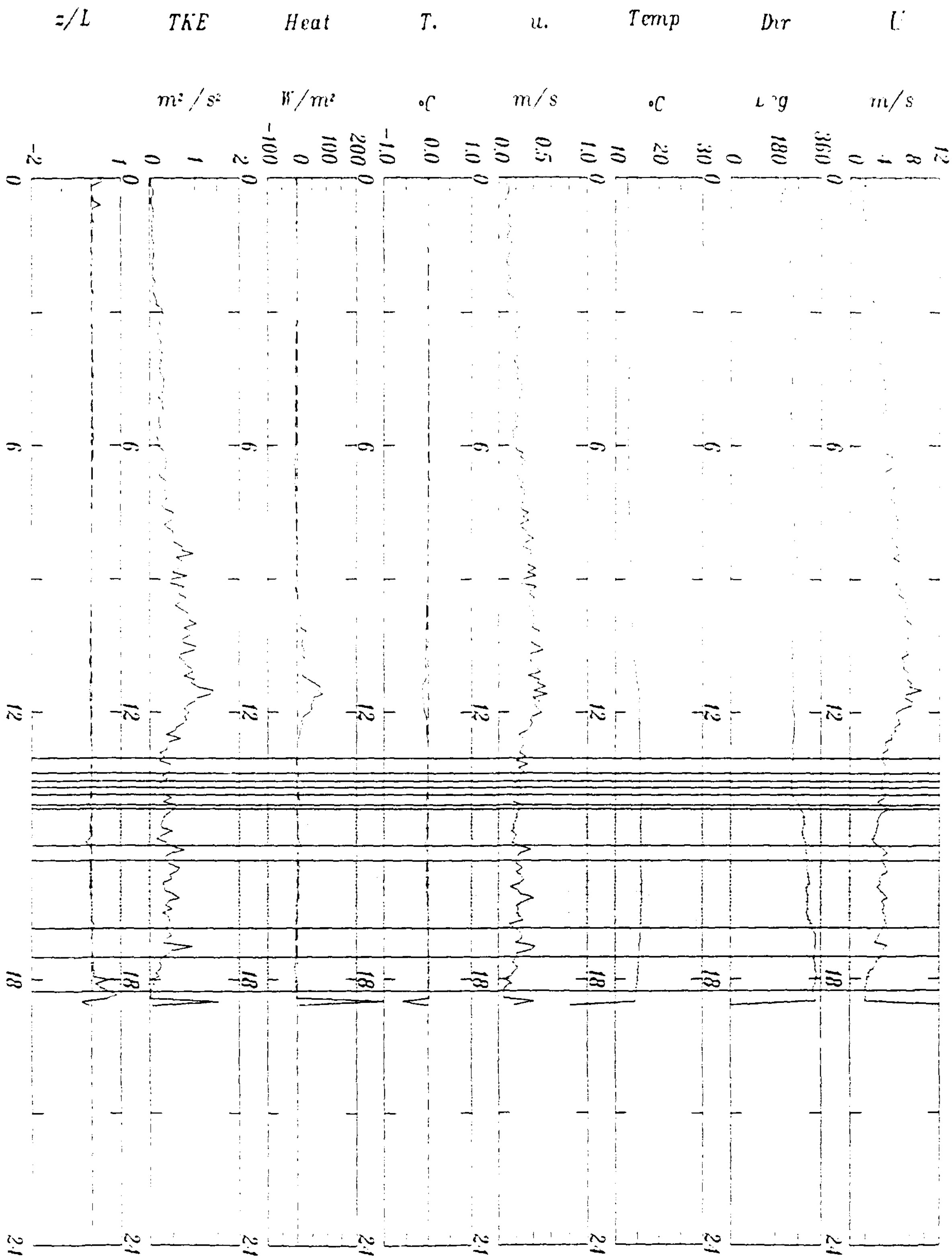

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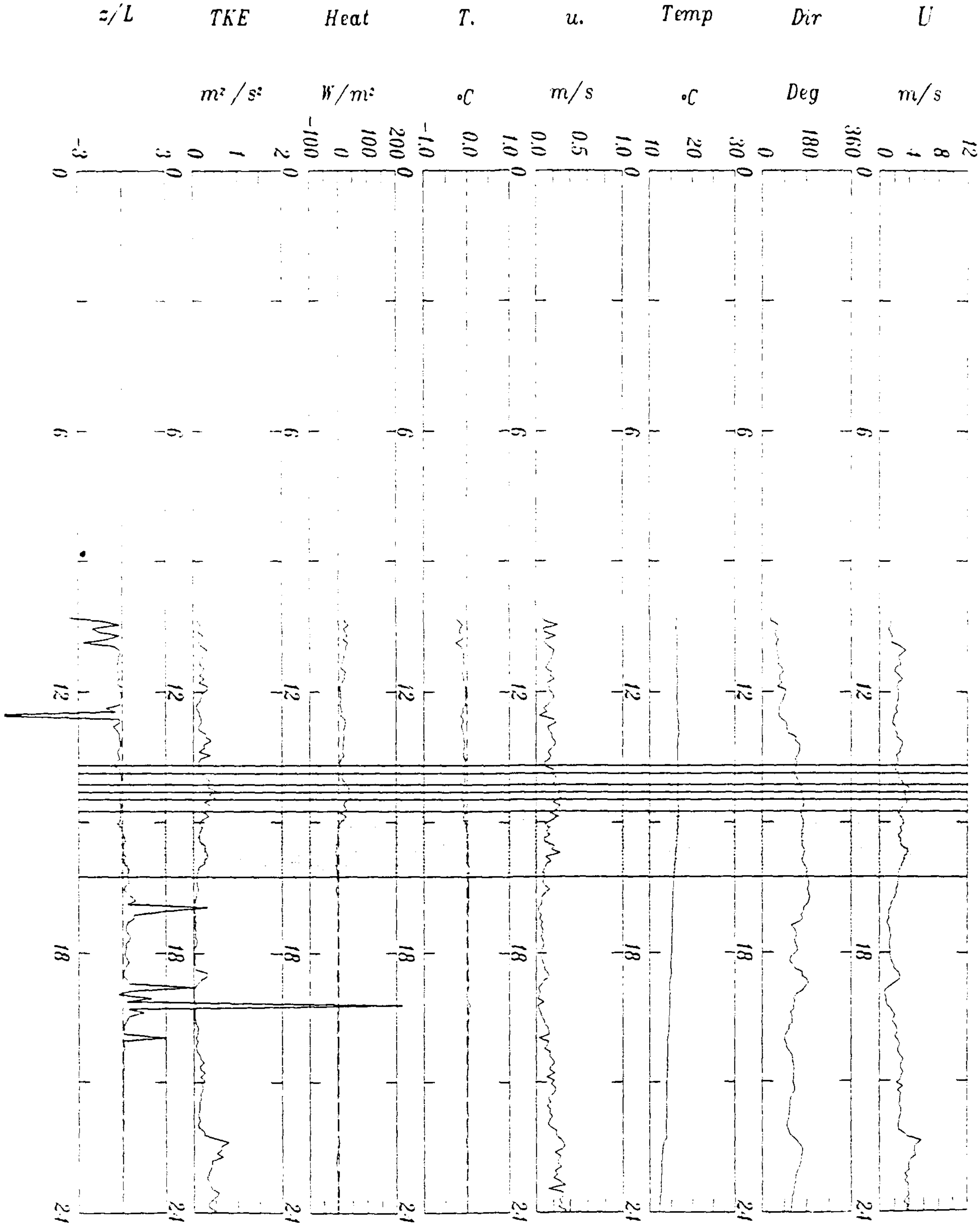

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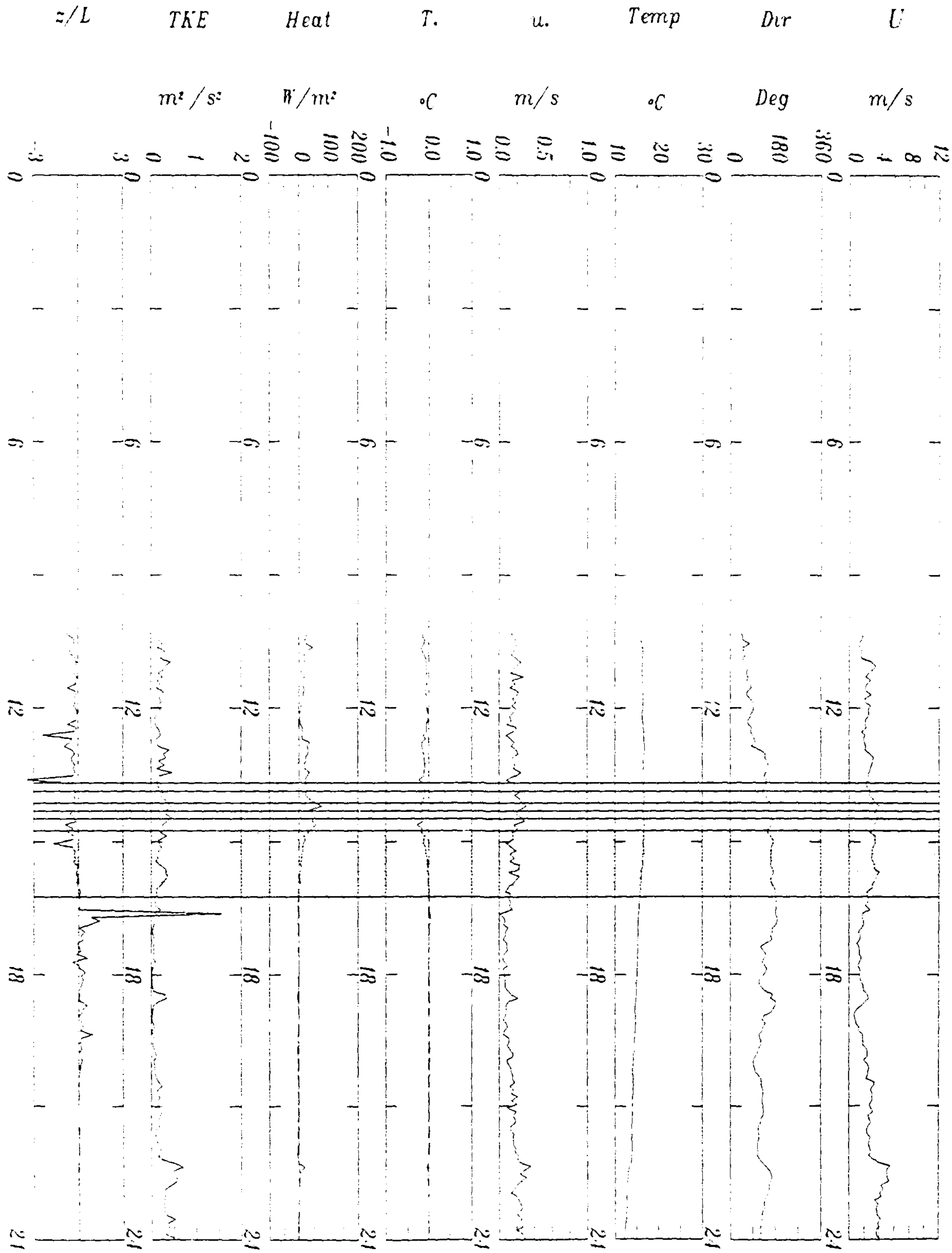

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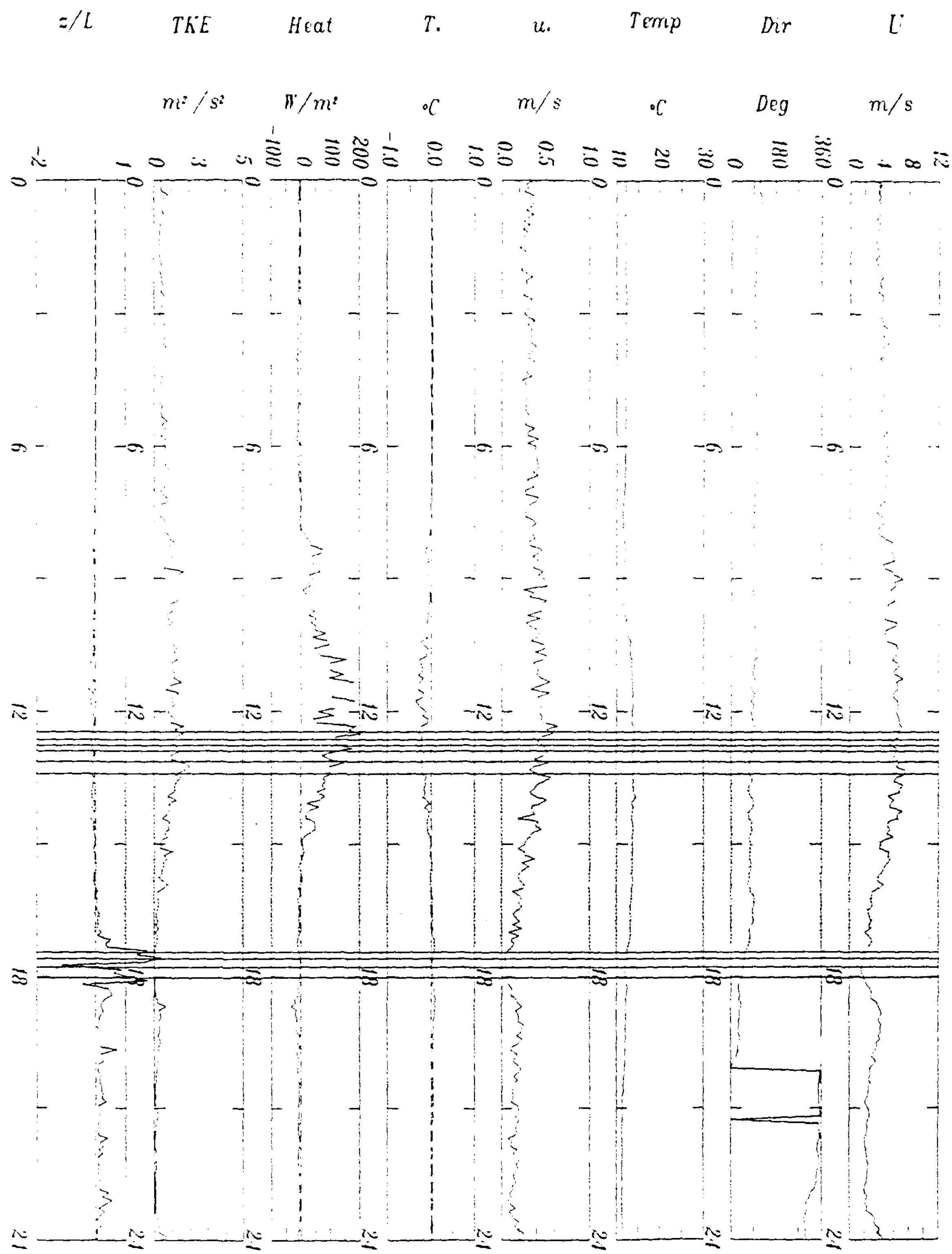

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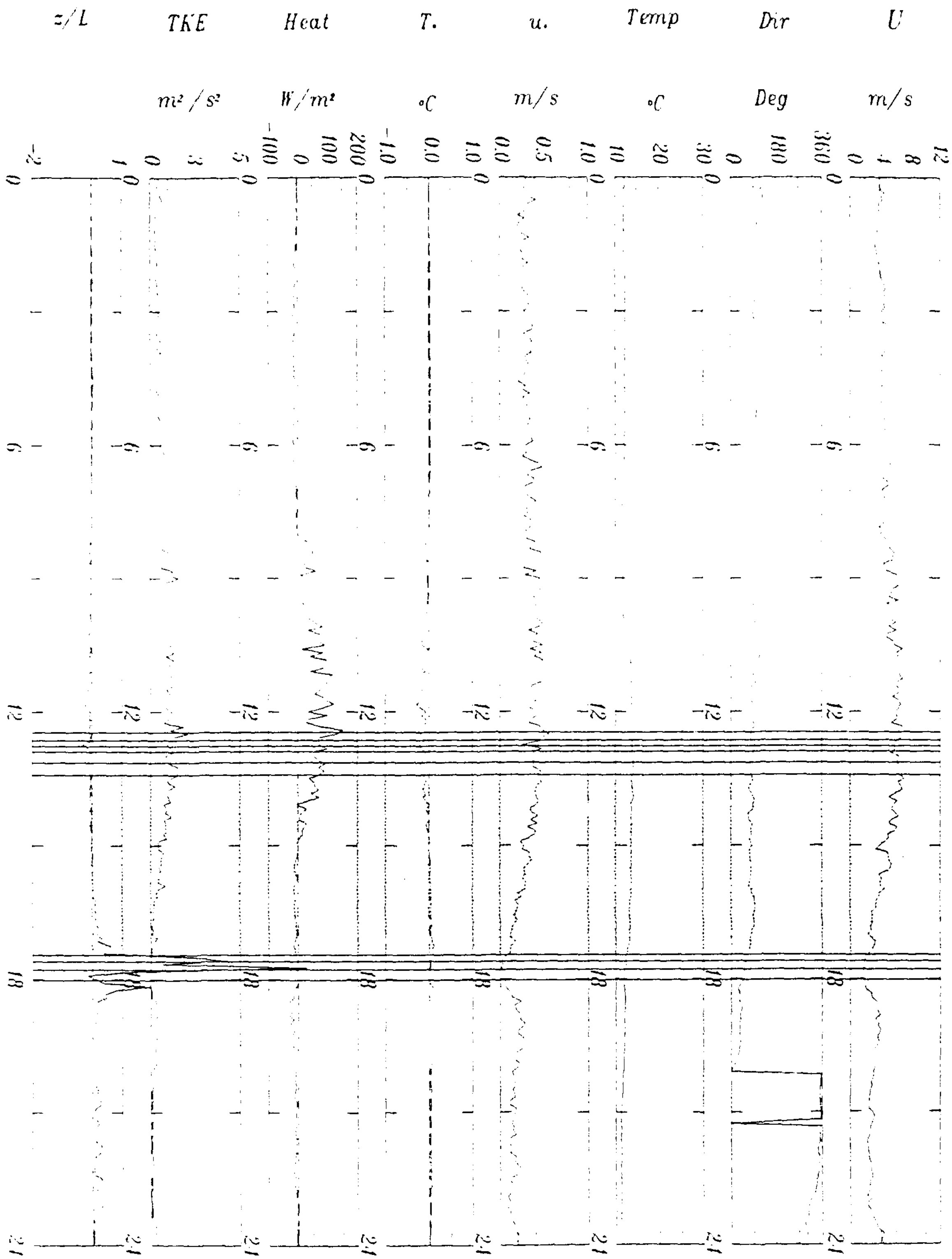

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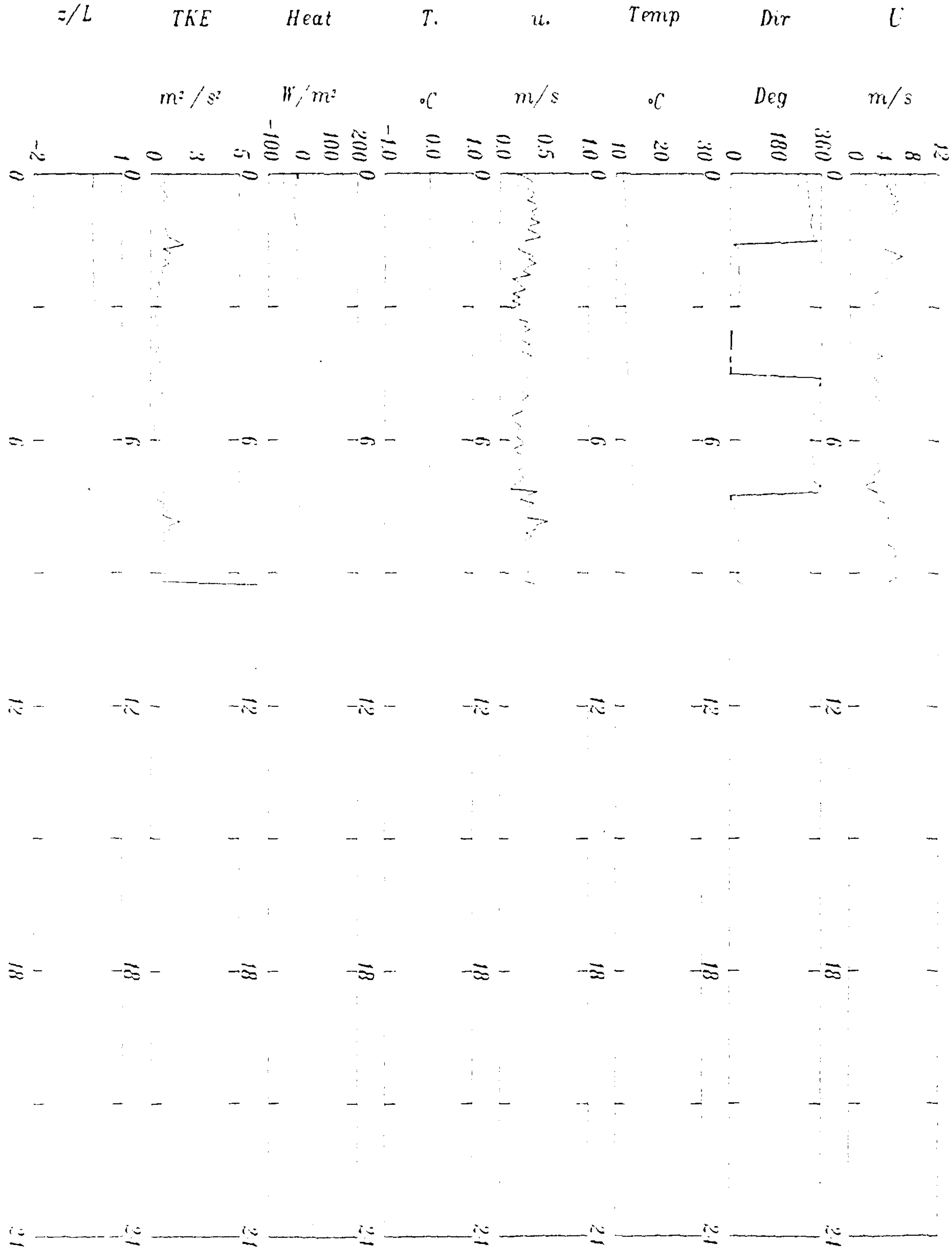

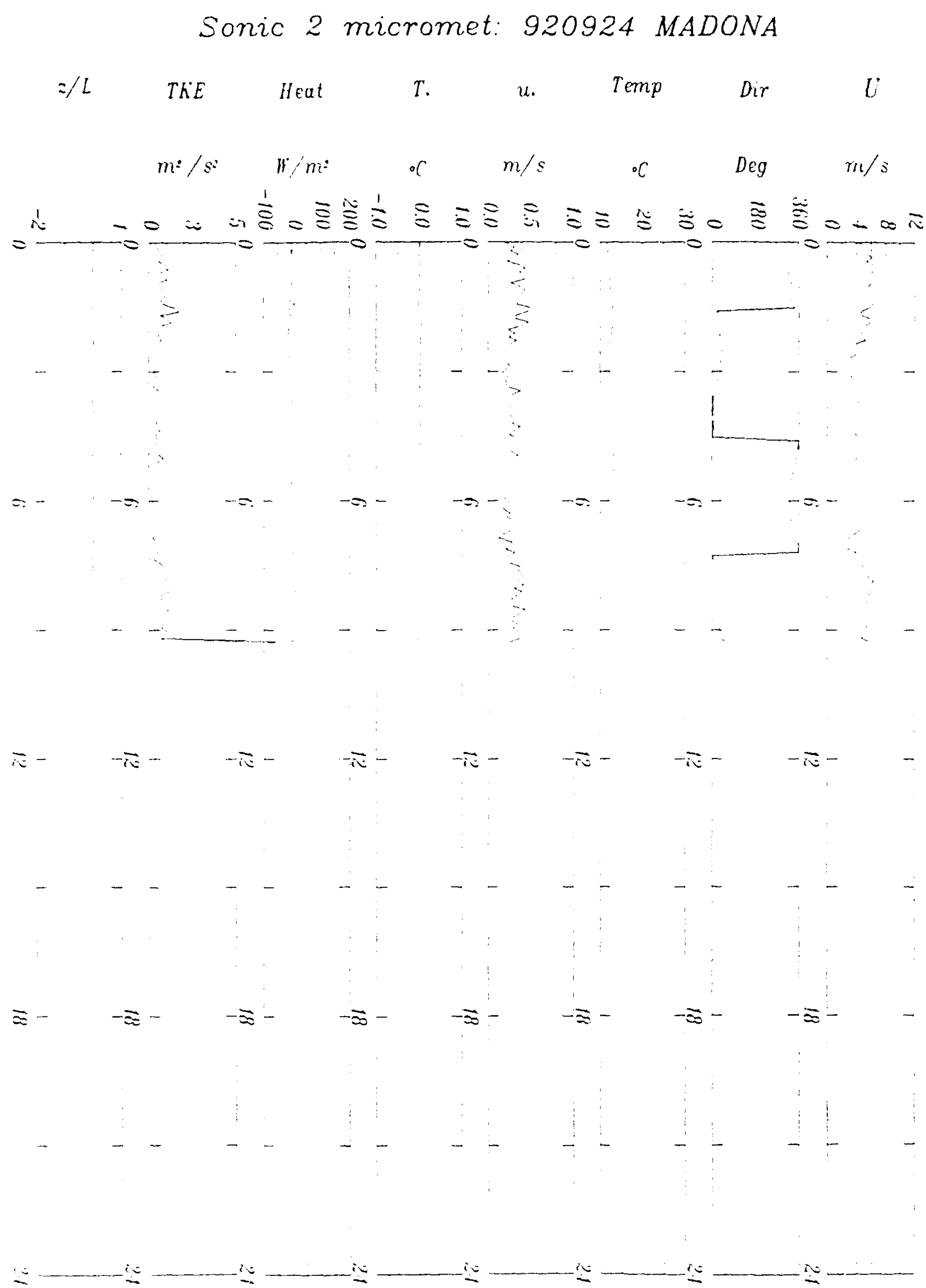

Sonic 2 micromet: 920924 MADONA
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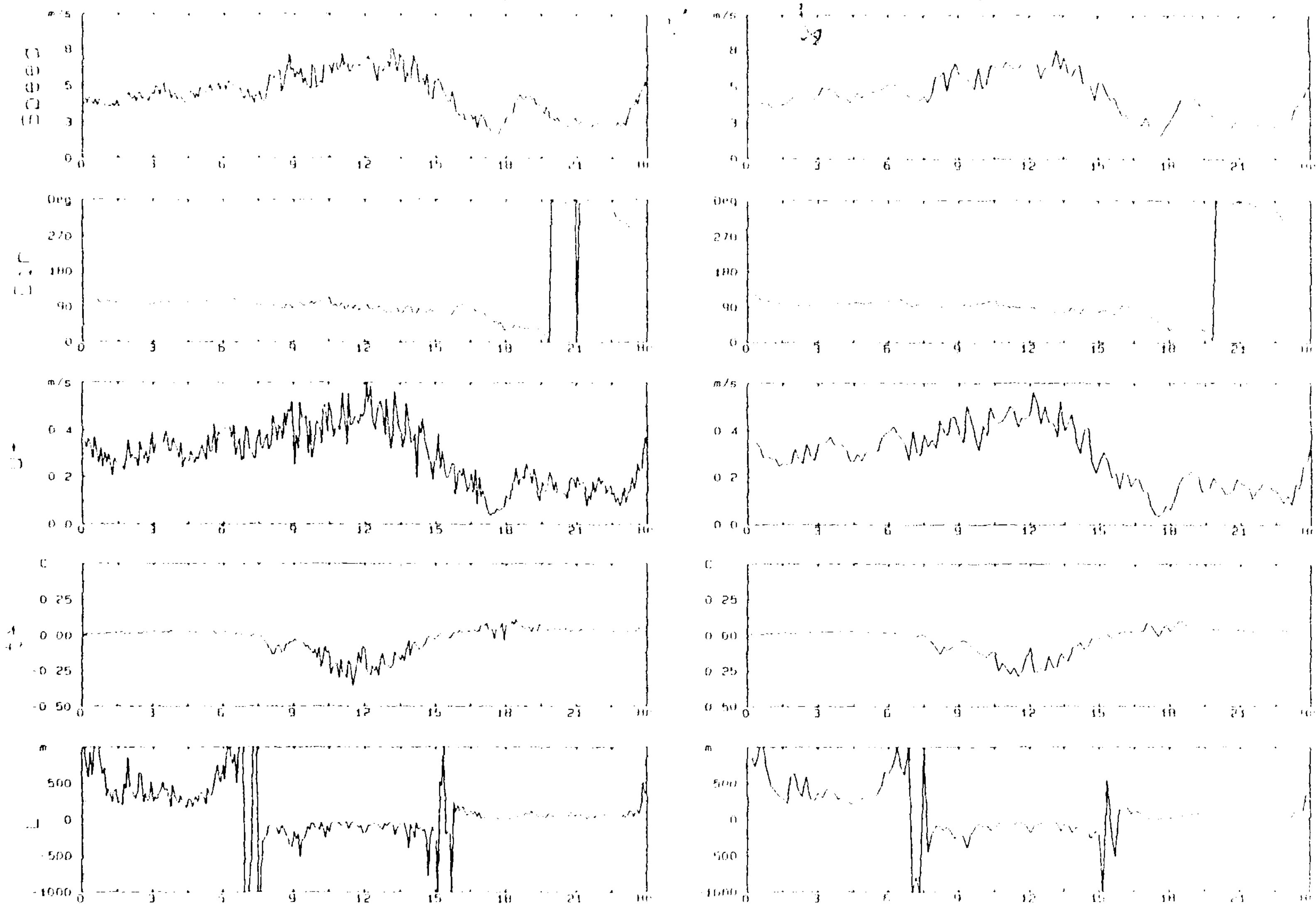
APPENDIX II.2

Porton, 23/9 comparison of 1 and 10 min stats, Sonic 1



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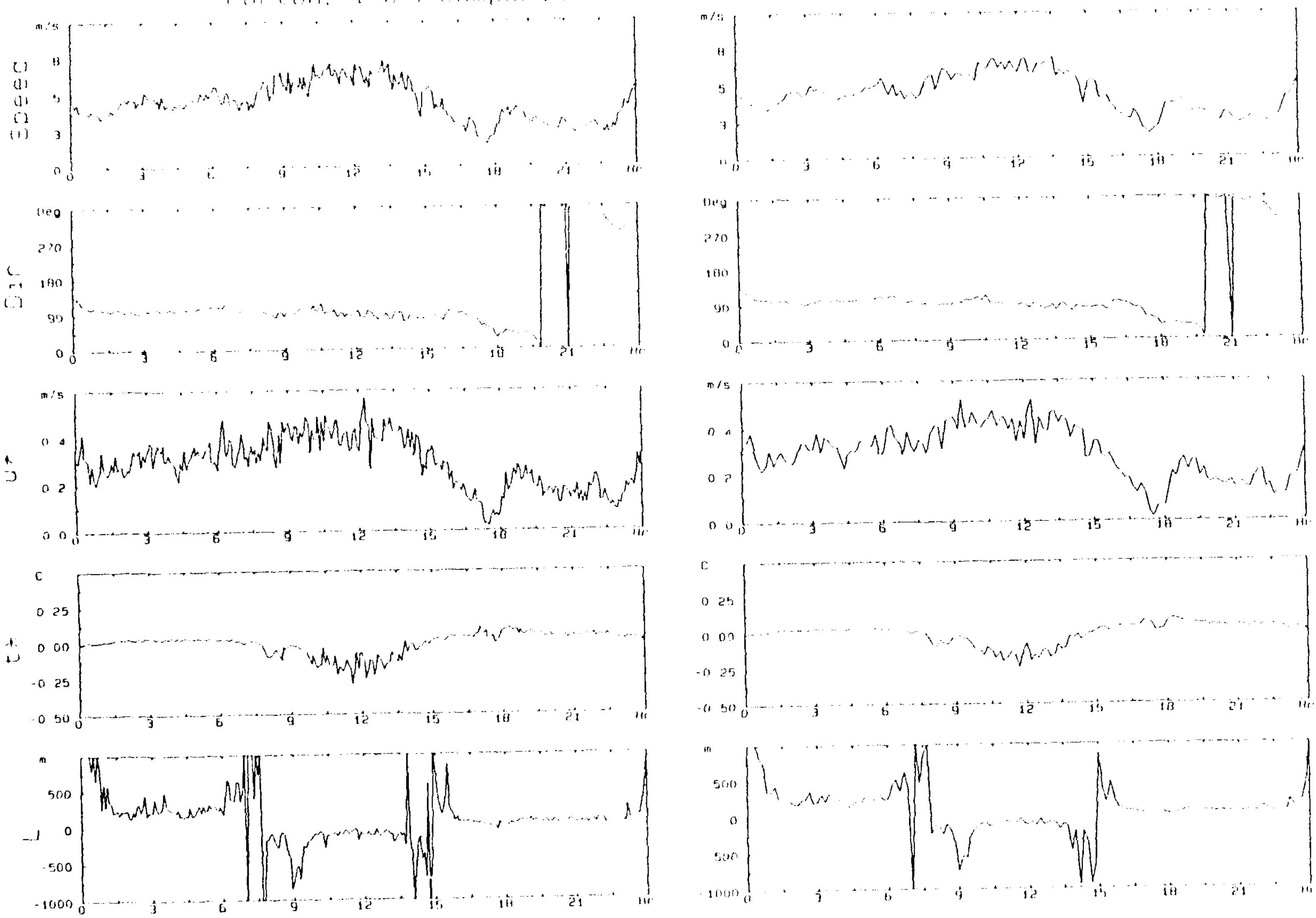


TABLE III.1 a)

Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad14b	-	---	13:52:00	-	-	--	--
mad14c	-	---	14:00:15	-	-	--	--
mad14d	+	---	14:08:?	-	-	--	--
mad14e	+	---	14:18:15	-	-	--	--
mad14f	-	---	14:28:30	-	0^0	--	--
mad14g	+	puff	14:54:?	2.3	-	S14-2	--
mad14h	+	cont	15:29-16:11	1.0	-	S14-3	L14-3
mad14i	+	----	16:14-16:33	-	-	--	--
mad14j	+	----	16:35-16:43	-	-	--	--
mad14k	+	----	16:47-17:43	-	-	--	--
mad15a	+	puff	13:29:00	2.9	-	S15-1	L15-1
mad15b	+	-	13:38:50	-	-	--	--
mad15c	+	---	13:45:17	-	-	--	--
mad15d	+	---	13:53:00	-	-	--	--
mad15e	+	---	14:01:30	-	-	--	--
mad15f	+	---	14:09:00	-	-	--	--
mad15g	+	---	14:15:30	-	-	--	--
mad15h	+	cont	15:00-15:14	1.0	-	--	--
mad15i	+	----	15:16-15:43	-	-	--	--
mad15j	+	----	15:46-16:10	-	-	--	--
mad15k	+	----	16:13-16:30	-	-	--	--
mad15l	+	----	16:33-16:39	-	-	--	--
						--	--
mad15m	+	puff	17:19:00	2.9	-	--	--
mad15n	+	---	17:48:10	-	-	--	--

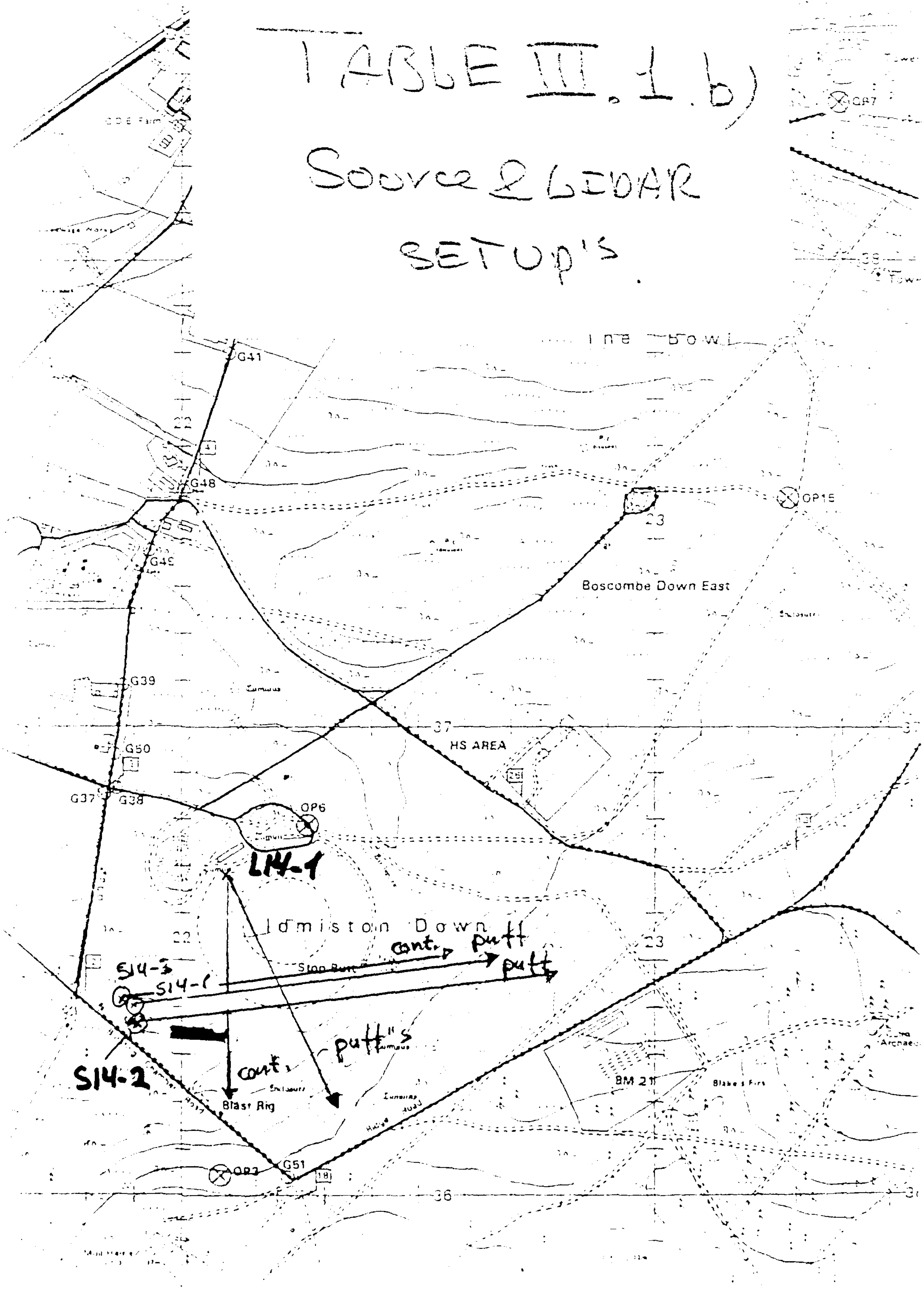
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad16a	+	puff	14:04:00	1.0	-8m oT.	S16-1	L16-1
mad16b	+	---	14:34:45	-	--	--	--
mad16c	-	---	14:51:20	-	--	--	--
mad16d	+	---	15:02:10	-	--	--	--
mad16e	-	---	16:00:00	-	--	--	--
mad16f	+	---	?16:15:30	-	--	--	--
mad16g	+	---	16:26:00	-	--	--	--
mad16h	+	---	16:39:15	-	--	--	--
mad16i	+	---	16:52:15	-	--	--	--
mad16j	+	---	17:04:30	-	--	--	--
mad16k	+	---	17:18:00	-	--	--	--
mad16l	+	---	17:30:00	-	--	--	--
mad16m	+	---	17:48:45	-	--	--	--
mad16n	+	---	18:12:50	-	--	--	--
mad16o	+	---	18:42:32	-	--	--	--
mad18a	+	cont	17:56-18:37	1.0	$1\text{-}2^0$	S18-1	L18-1
mad19a	+	puff	13:15:00	6.0	$2\text{-}3^0$	S19-1	L19-1A
mad19b	+	---	?13:25:00	-	--	-	
mad19c	+	---	13:36:00	-	--	--	--
mad19d	-	---	13:47:23	-	--	--	--
mad19e	+	cont	15:09-15:52	1.0	3^0	S19-1	L19-1
mad19f	-	puff	16:10:40	6.0	--	--	L19-2
mad19g	+	---	16:26:35	-	--	--	--
mad19h	+	---	17:49:30	-	5m oT	S19-3	L19-2

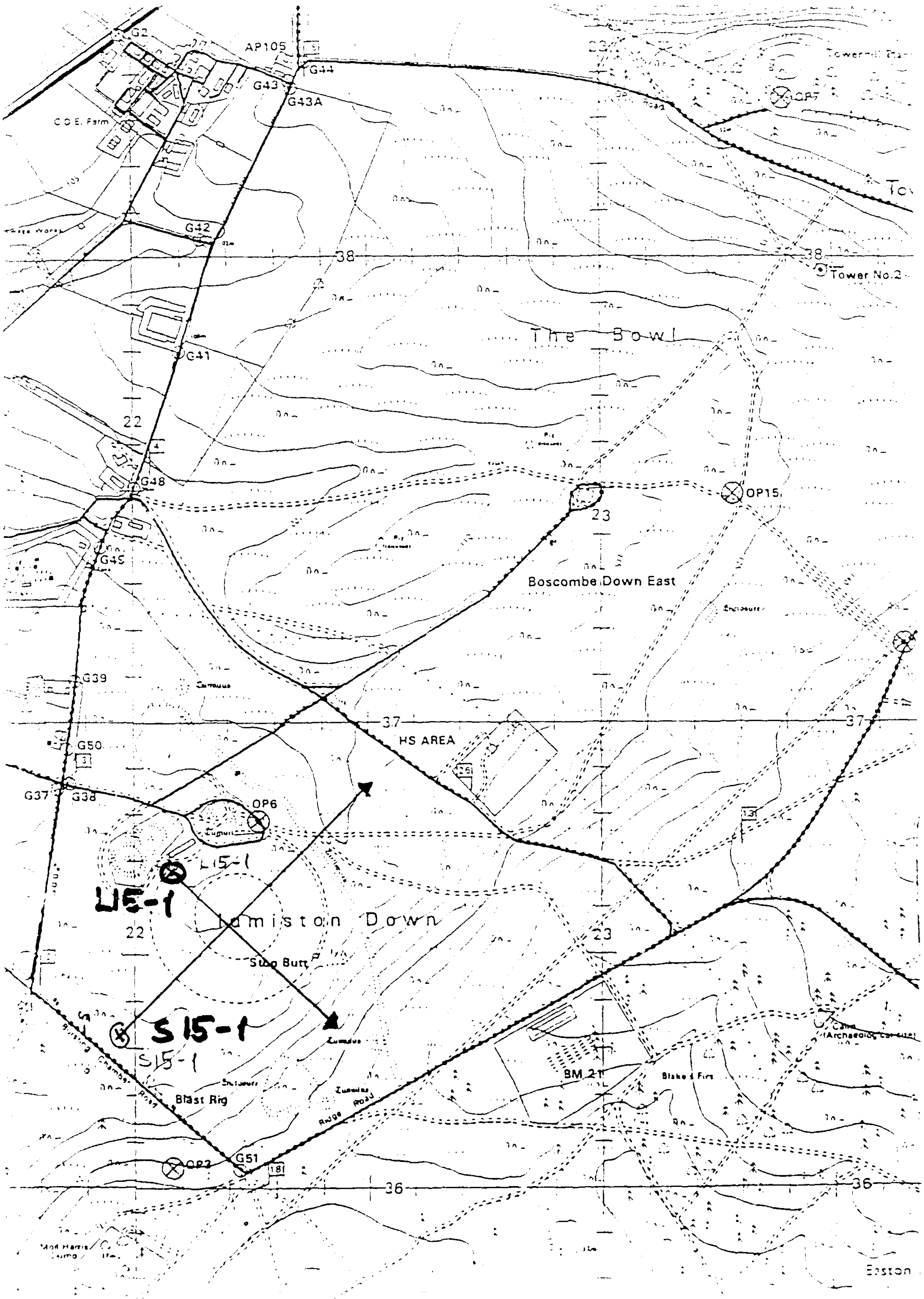
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad19i	+	---	18:01:00	-	--	--	--
mad19j	-	---	18:14:30	-	--	--	--
mad19k	+	---	18:23:00	-	--	--	--
mad19l	+	---	18:30:00	-	--	--	--
mad20a	-	cont	12:07-12:29	1.0	2m oT	S20-1	L20-1
mad20b	(-)	---	12:47-13.01	-	--	--	--
mad20c	+	puff	14:55:22	6.0	2m oT	S20-2	L20-2
mad20d	-	---	15:13:30	-	--	--	--
mad20e	-	---	15:30:00	-	--	--	--
mad20f	-	---				S20-3	L20-3
mad20g	-	---				--	--
mad20h	-	---				--	--
mad20i	-	---				--	--
mad20j	+	---	18:32:00	1.0	--	--	--
mad20k	+	---	18:41:00	-	--	--	--
mad20l	+	---	18:49:00	-	--	--	--
mad20m	+	---	18:56:00	-	--	--	--
mad20n	+	---	19:04:00	-	--	--	--
mad20o	+	---	19:10:00	-	--	--	--
mad21a	+	puff	13:22:30	1.0	0^0	S21-1	L21-1
mad21b	+	---	13:32:40	-	--	--	--
mad21c	+	---	13:41:30	-	--	--	--
mad21d	+	---	13:51:20	-	--	--	--
mad21e	+	---	14:04:30	-	--	--	--

Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3⁰	S14-1	L14-1
mad21f	(+)	cont	14:42-14:59	1.0	0⁰	S21-2	L21-2
mad21g	+	cont	15:19-15:43	-	--	--	L21-3
mad21h	(+)	---	15:45-16:17	-	--	--	--
mad21i	(-)	---	16:18-16:40	-	--	--	--
mad21j	-	---	(-)	-	--	--	--
mad21k	+ +	cont	17:31-18:19	1.0	--	S21-4	L21-4
mad22a	+	puff	13:41:25	2.3	--	S22-1	L22-1
mad22b	+	---	13:52:13	-	--	--	--
mad22c	+	---	14:07:45	-	--	--	--
mad22d	+	---	14:18:35	-	--	--	--
mad22e	+	---	14:29:00	-	--	--	--
mad22f	+	cont	14:51-16:13	1.0	scan	S22-2	--
mad23b	(-)	puff	12:38:30	2.3	2m oT	S23-1	L23-1
mad23c	(+)	---	12:46:30	-	--	--	--
mad23d	(-)	---	12:54:00	-	--	--	--
mad23e	(-)		13:08:30	-	--	--	--
mad23f	+	cont	13:32-14:46	1.0	scan	S23-2	--
mad23g	+	---	15:00-17:31	-	--	--	--
mad23h	+	puff	17:36:30	2.3	2m oT	S23-1	--
mad23i	+	---	17:47:30	-	--	--	--

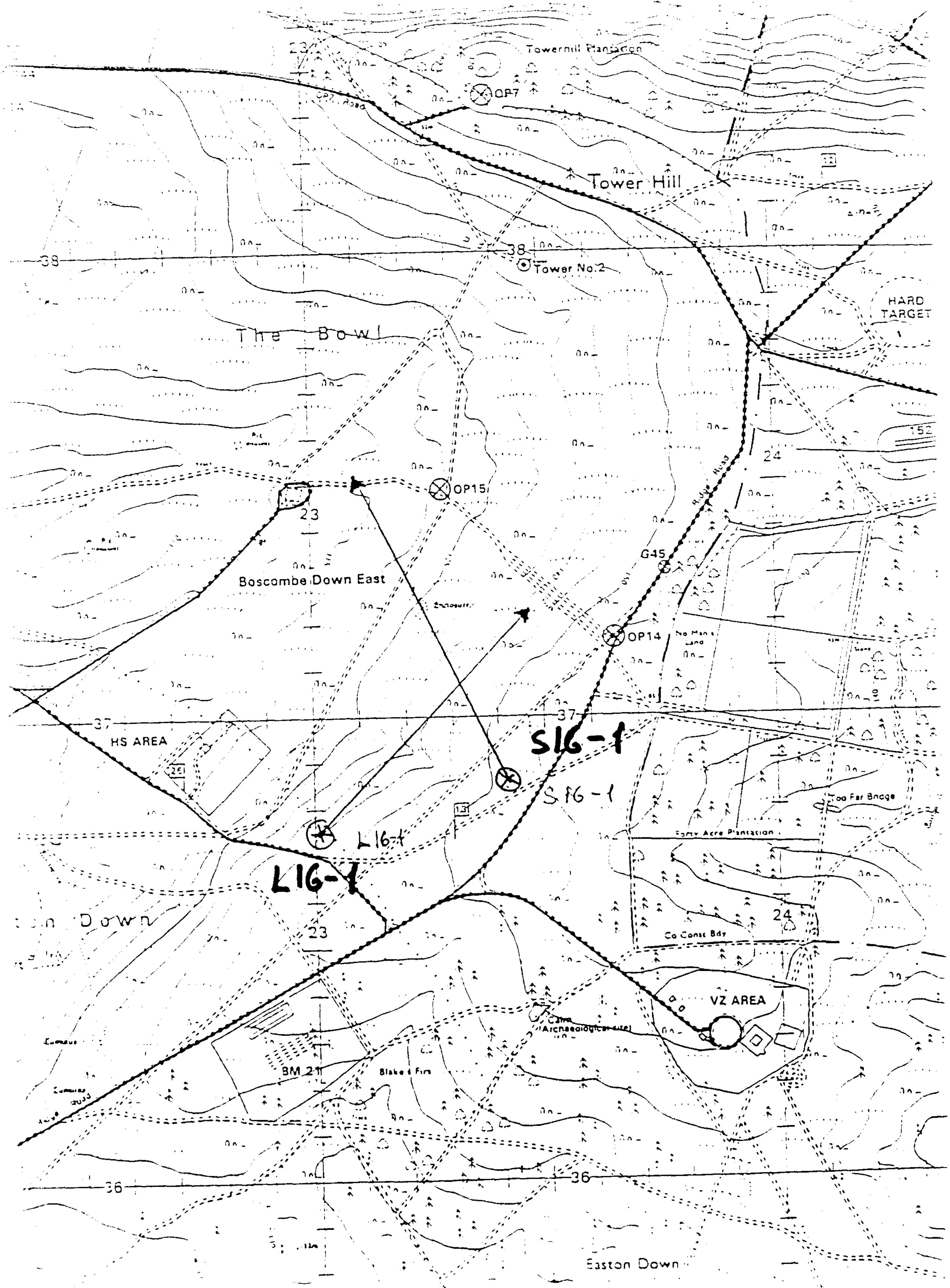
TABLE III.1 b)

Source & LIDAR SETUP's.

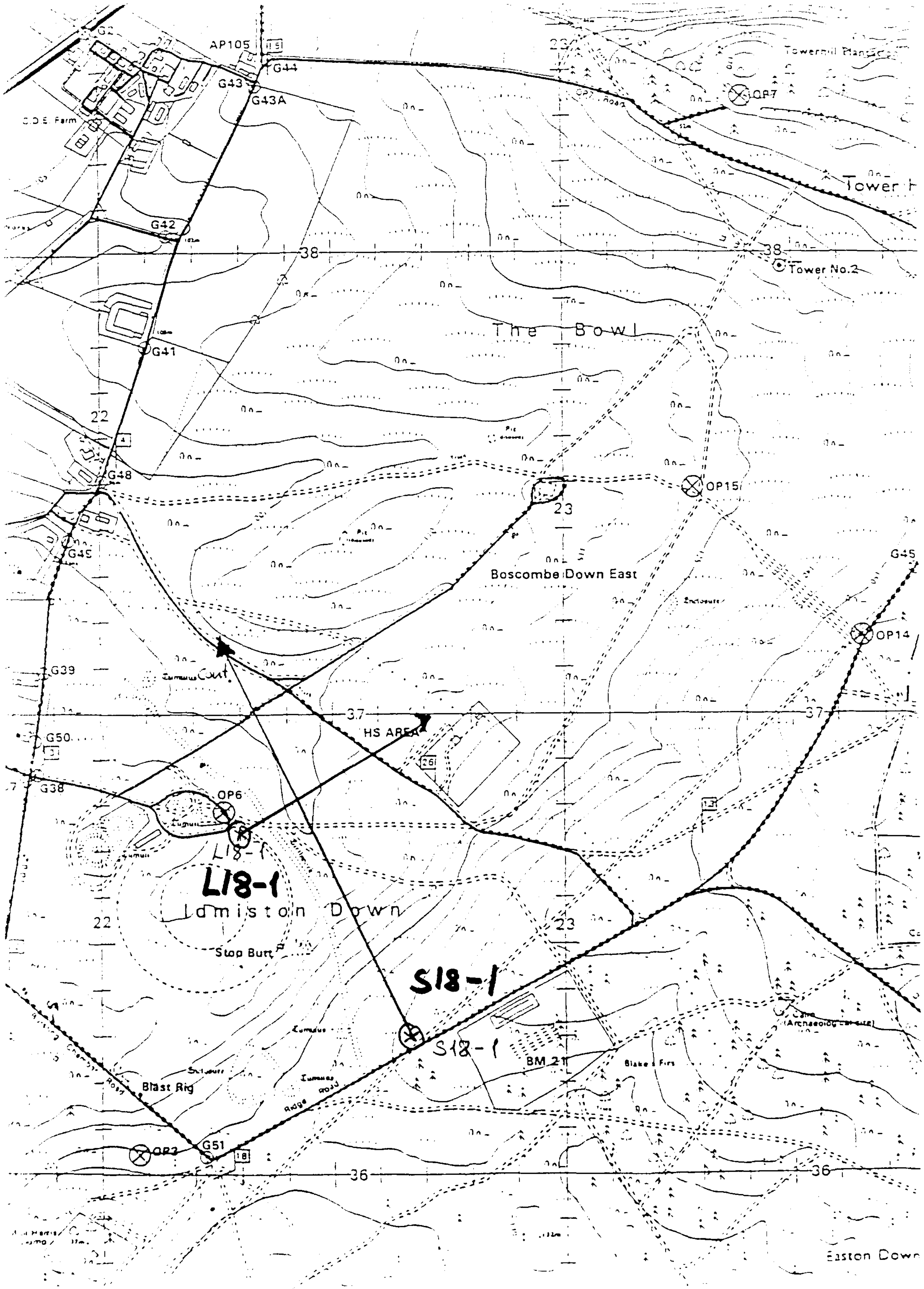




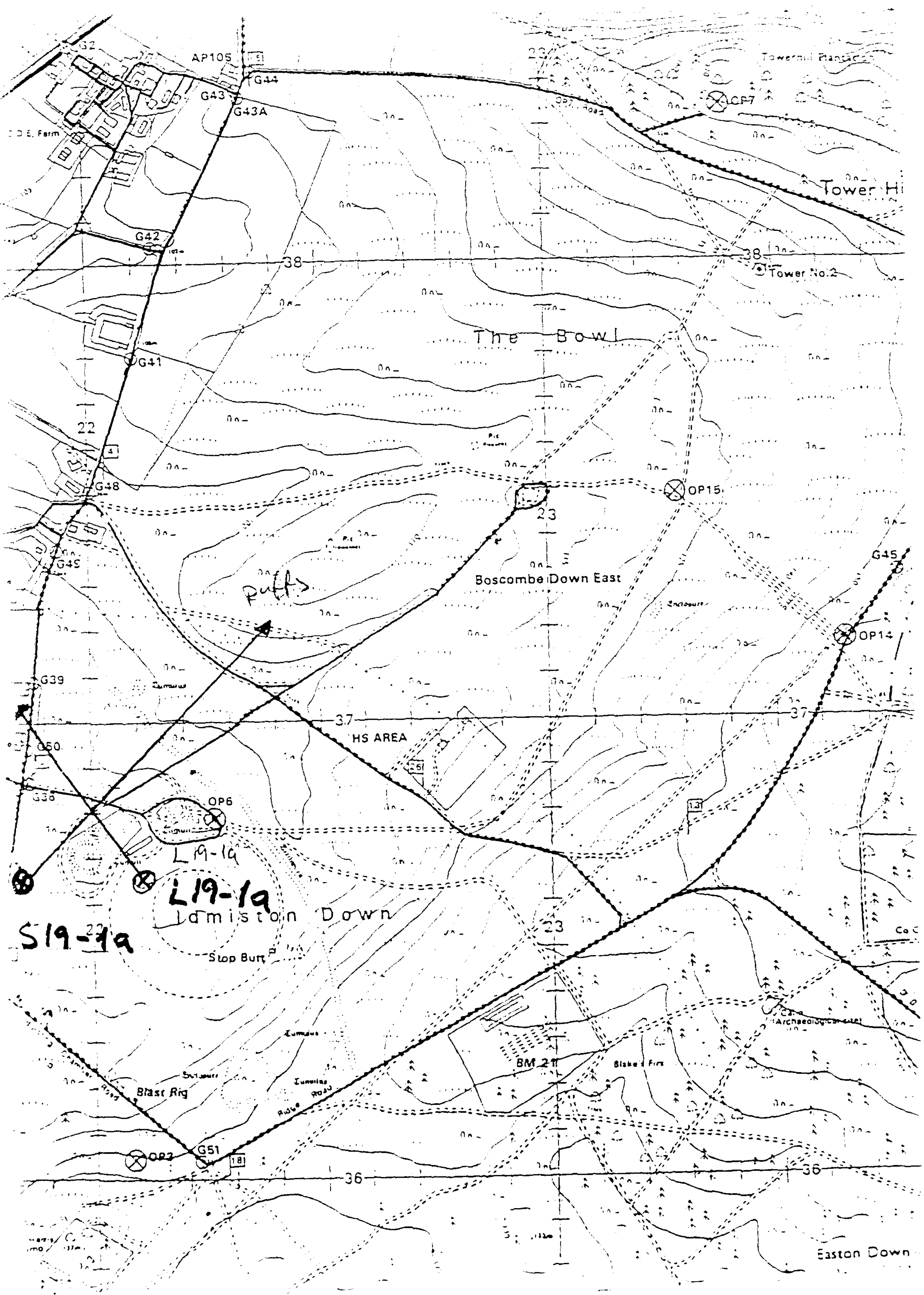
G2
AP105
G44
G43
G43A
C.O.E. Farm
Towerhill Barn
OP7
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
G39
37
HS AREA
G50
G37
G38
OP6
L15-1
UE-1
Idmiston Down
22
23
Stop Butt
S15-1
S15-1
BM 21
Blast Rig
Ridge Road
G51
OP2
36
36
Easton



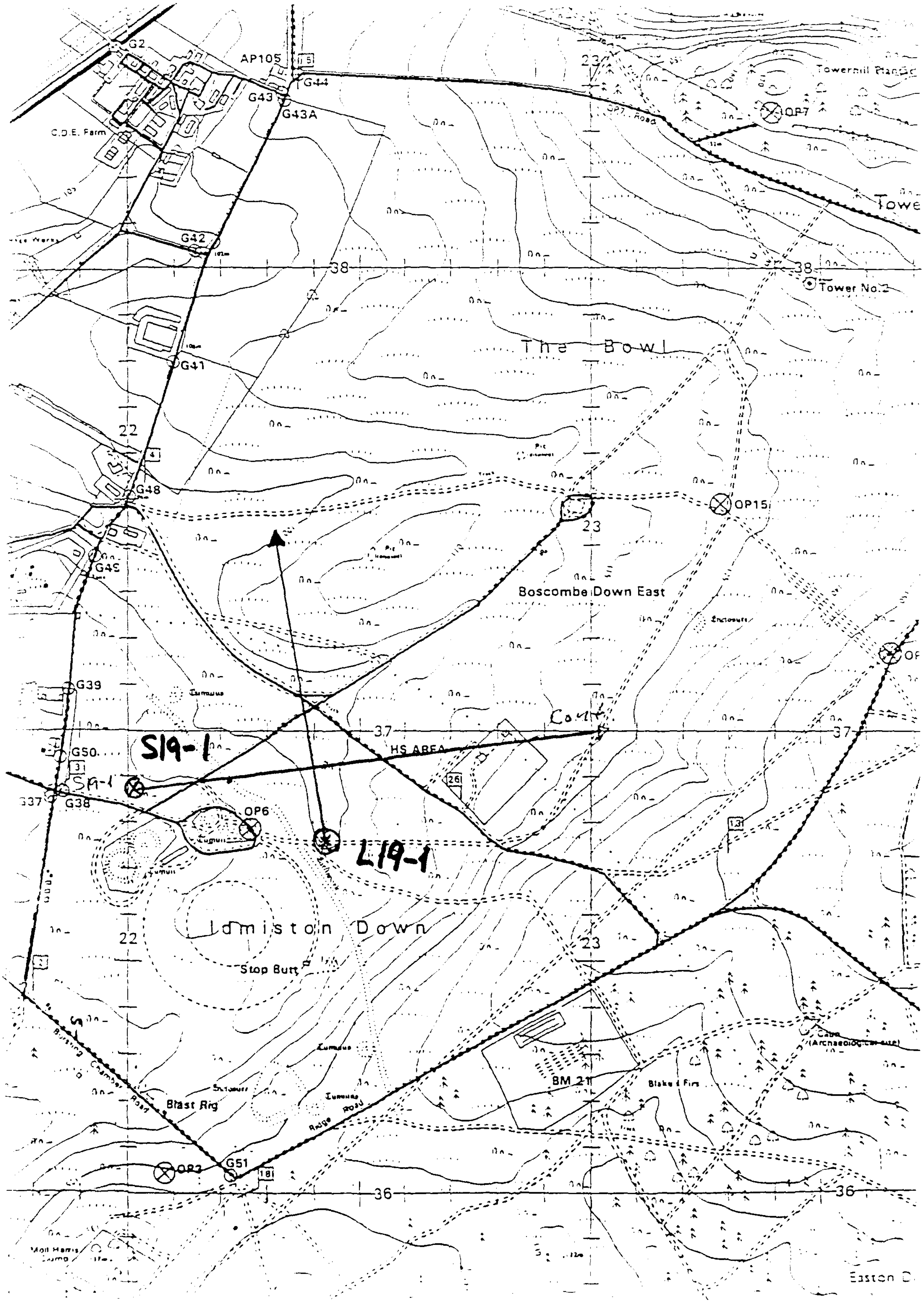
Towerhill Plantation
OP7
Tower Hill
38
Tower No.2
HARD TARGET
The Bowl
OP15
23
Boscombe Down East
G45
OP14
24
37
HS AREA
SIG-1
SIG-1
LIG-1
LIG-1
Forty Acre Plantation
Too Far Bridge
Co Const Bdy
VZ AREA
BM 21
Blake's Firs
36
Easton Down

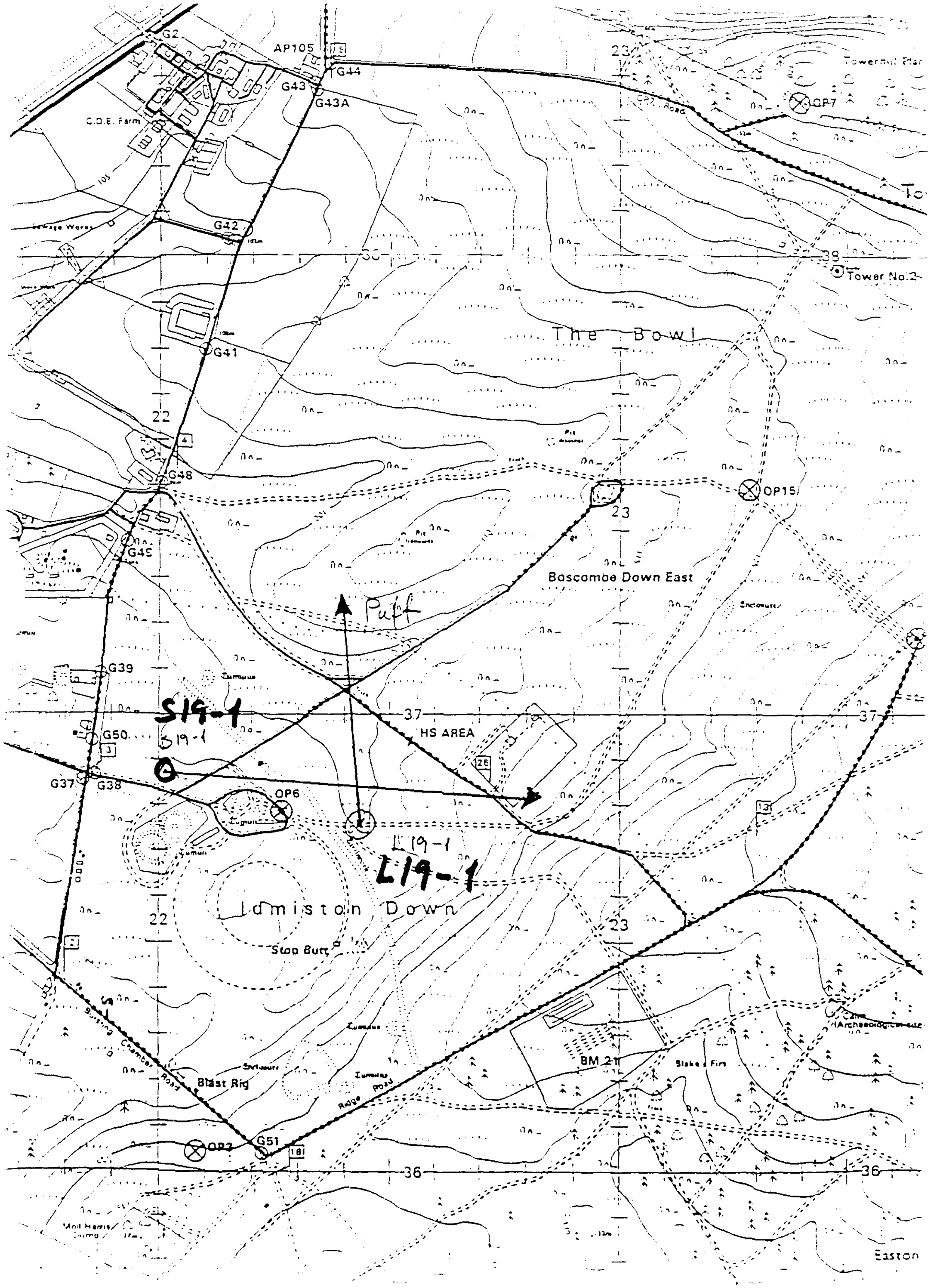


G2
AP105
G44
G43
G43A
C.D.E. Farm
Towerhill Plantation
OP7
Tower H
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G49
Boscombe Down East
G45
Enclosure
OP14
Cut
G39
Tumulus
37
HS AREA
G50
G38
OP6
L18-1
L18-1
Idmiston Down
22
23
Stop Butt
S18-1
S18-1
Cave (Archaeological site)
Tumulus
BM 21
Blake's Firs
Blast Rig
Ridge Road
OP3
G51
18
36
Easton Down

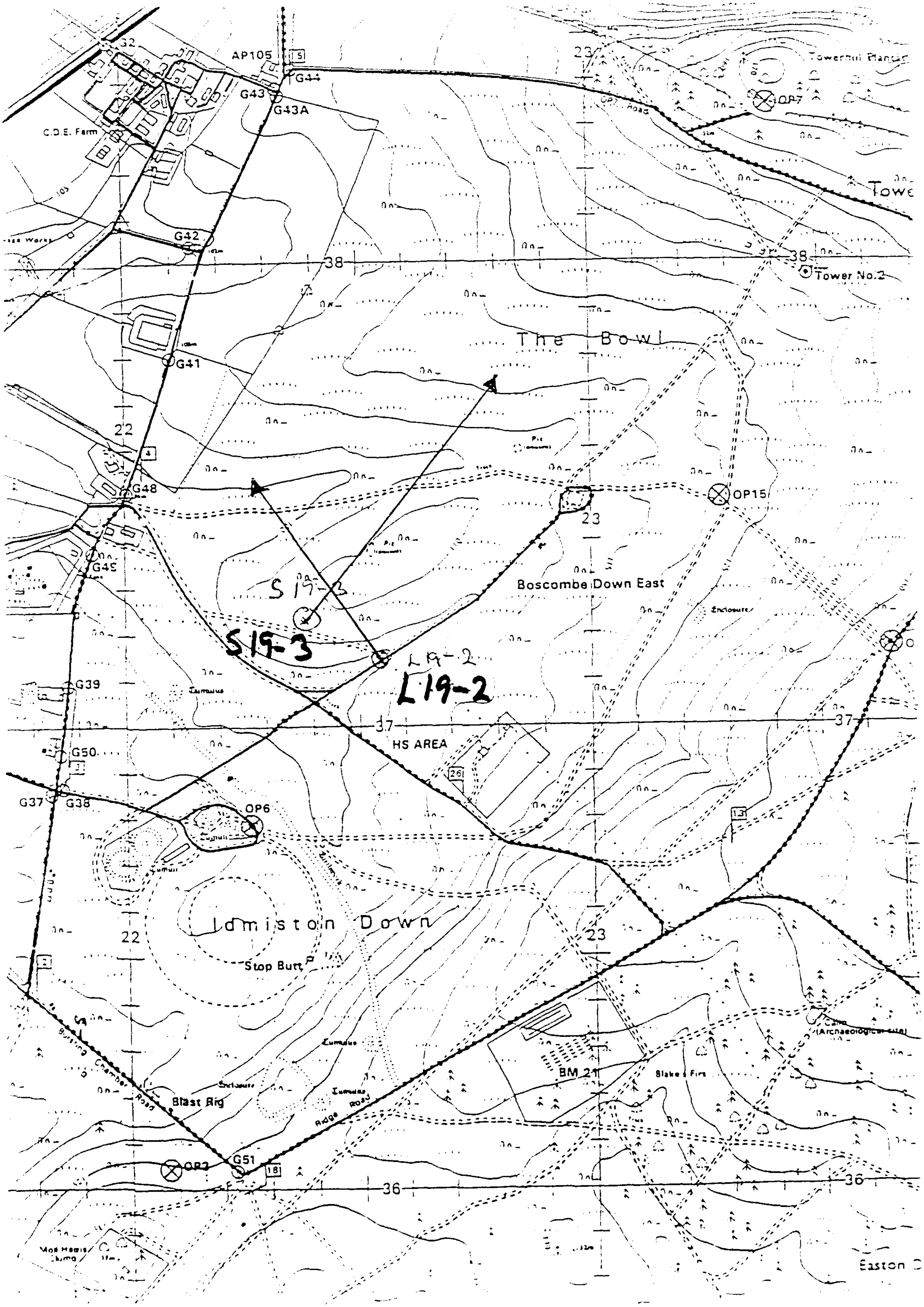


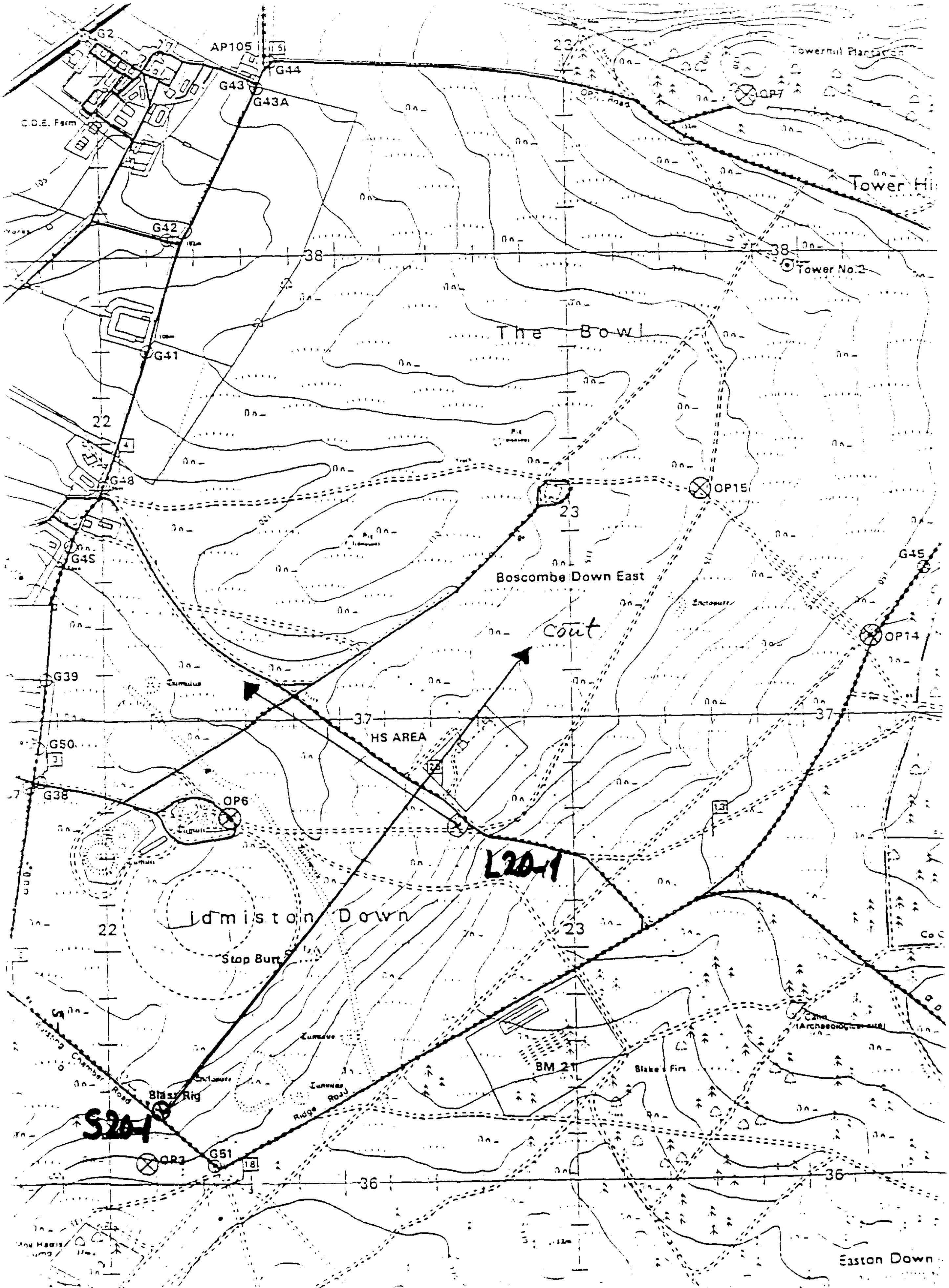
G2
AP105
G44
G43
G43A
Tower Hi
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
puffs
OP14
G39
37
HS AREA
G50
G38
OP6
L19-1a
S19-1a
Idmiston Down
Stop Butt
23
BM 211
Blake's Firs
Blast Rig
G51
OP2
36
Easton Down


G2
AP105
G44
G43
G43A
C.D.E. Farm
Towerhill Plantation
OP7
Towe
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G49
Boscombe Down East
Enclosure
G39
Tumulus
Cont
37
G50
S19-1
HS AREA
Sg-1
G37
G38
OP6
Tumuli
L19-1
Idmiston Down
Stop Butt
Bursting Chamber Road
Tumulus
BM 21
Blake's Firs
Blast Rig
Ridge Road
OP3
G51
36
Easton D

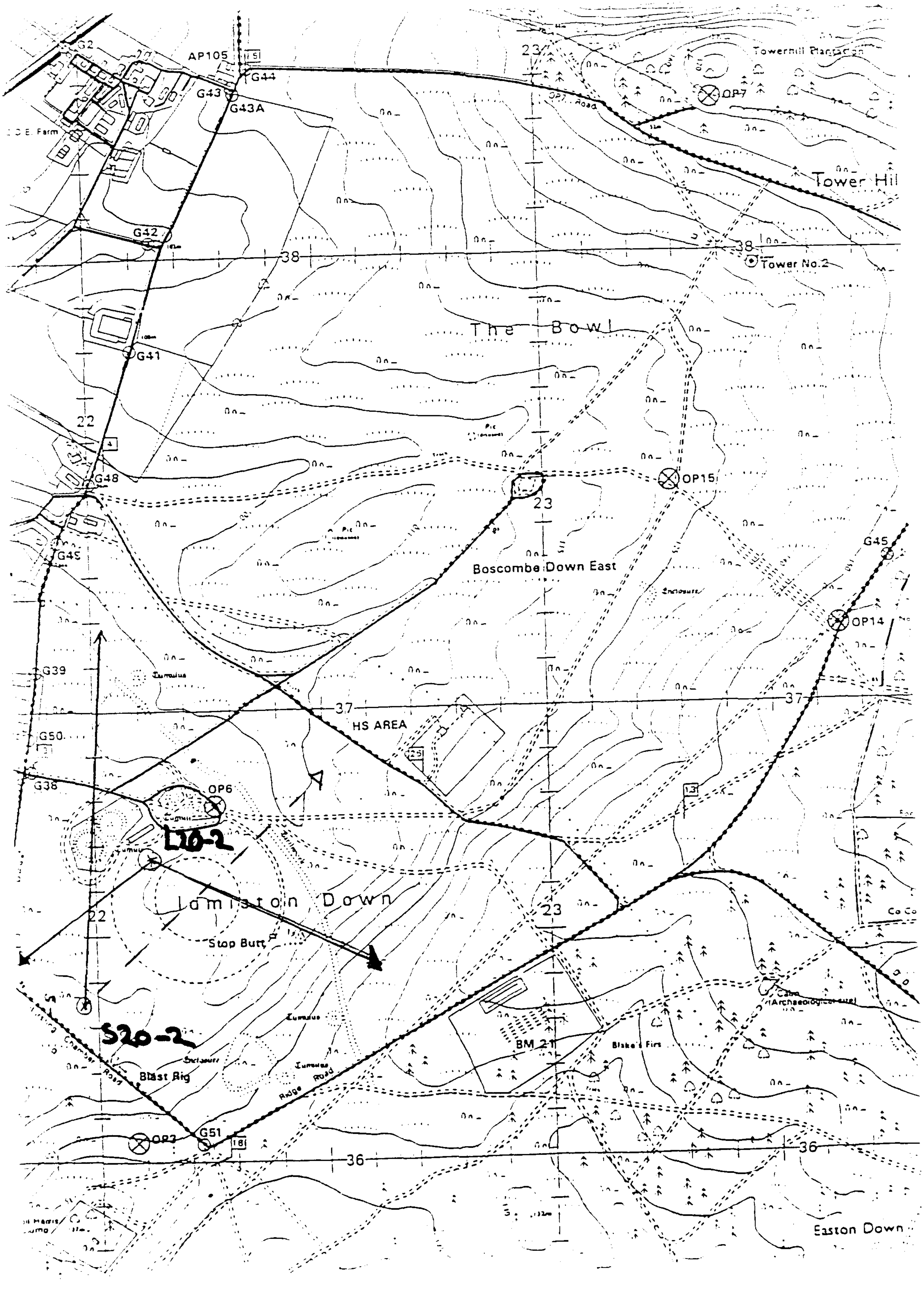


G2
AP105
G44
G43
G43A
C.D.E. Farm
Towermill Plantation
OP7
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
Puff
G39
S19-1
S19-1
37
HS AREA
G50
G37
G38
OP6
L19-1
L19-1
Idmiston Down
22
23
Stop Butt
Bursting Chamber Road
Blast Rig
Ridge Road
BM 21
Blakes Firs
OP3
G51
36
36
Easton

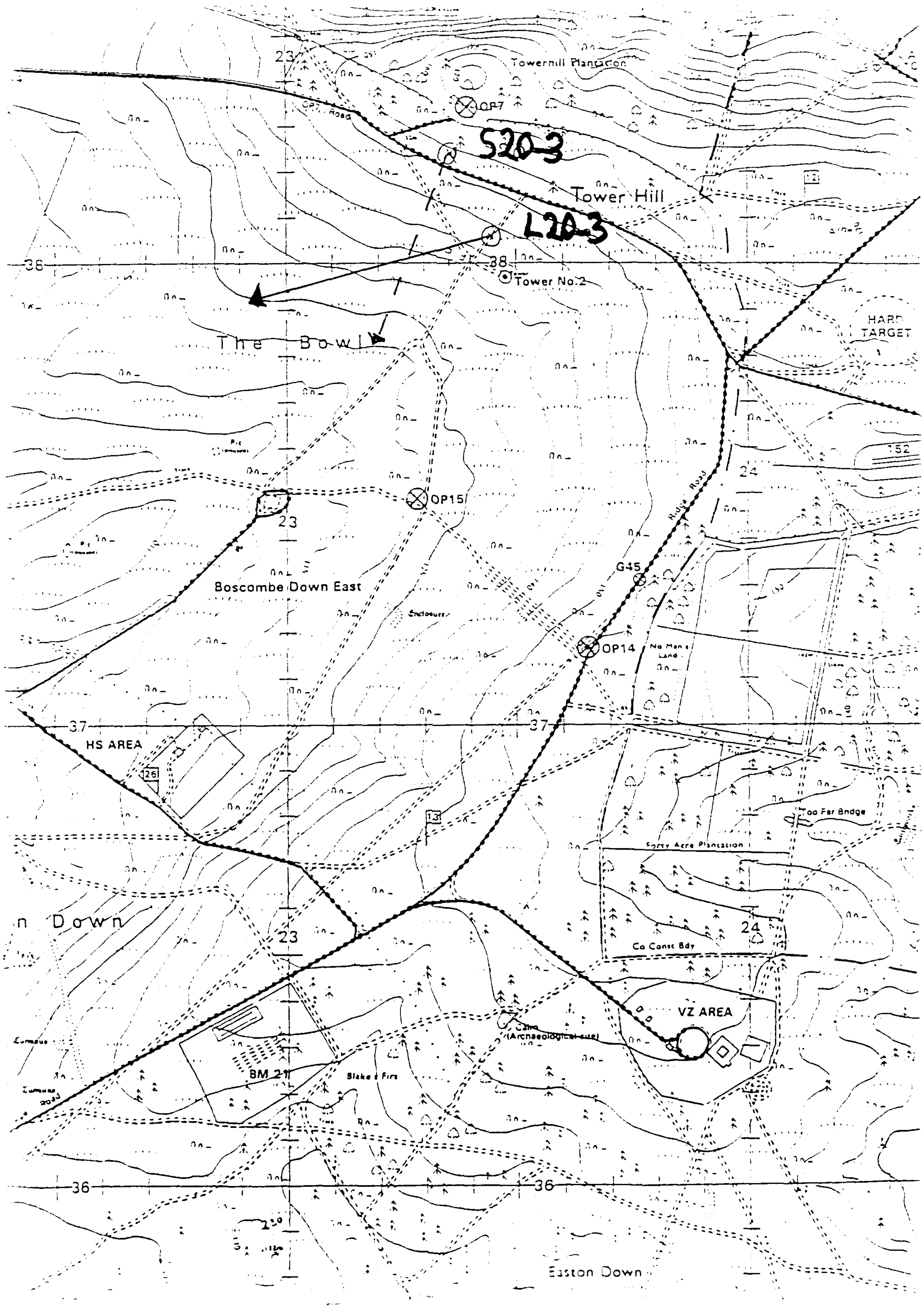

G32
AP105
15
G44
G43
G43A
C.D.E. Farm
OP7
Road
Tower No.2
38
G42
G41
The Bowl
22
4
G48
OP15
23
G45
Boscombe Down East
S19-3
S19-3
L19-2
L19-2
G39
Tumulus
37
HS AREA
G50
26
G37
G38
OP6
Tumuli
13
Idmiston Down
22
23
Stop Butt
Bursting Chamber Road
Blast Rig
Enclosure
Ridge Road
BM 21
Blake's Firs
Cairn (Archaeological site)
G51
OP3
18
36
Easton D



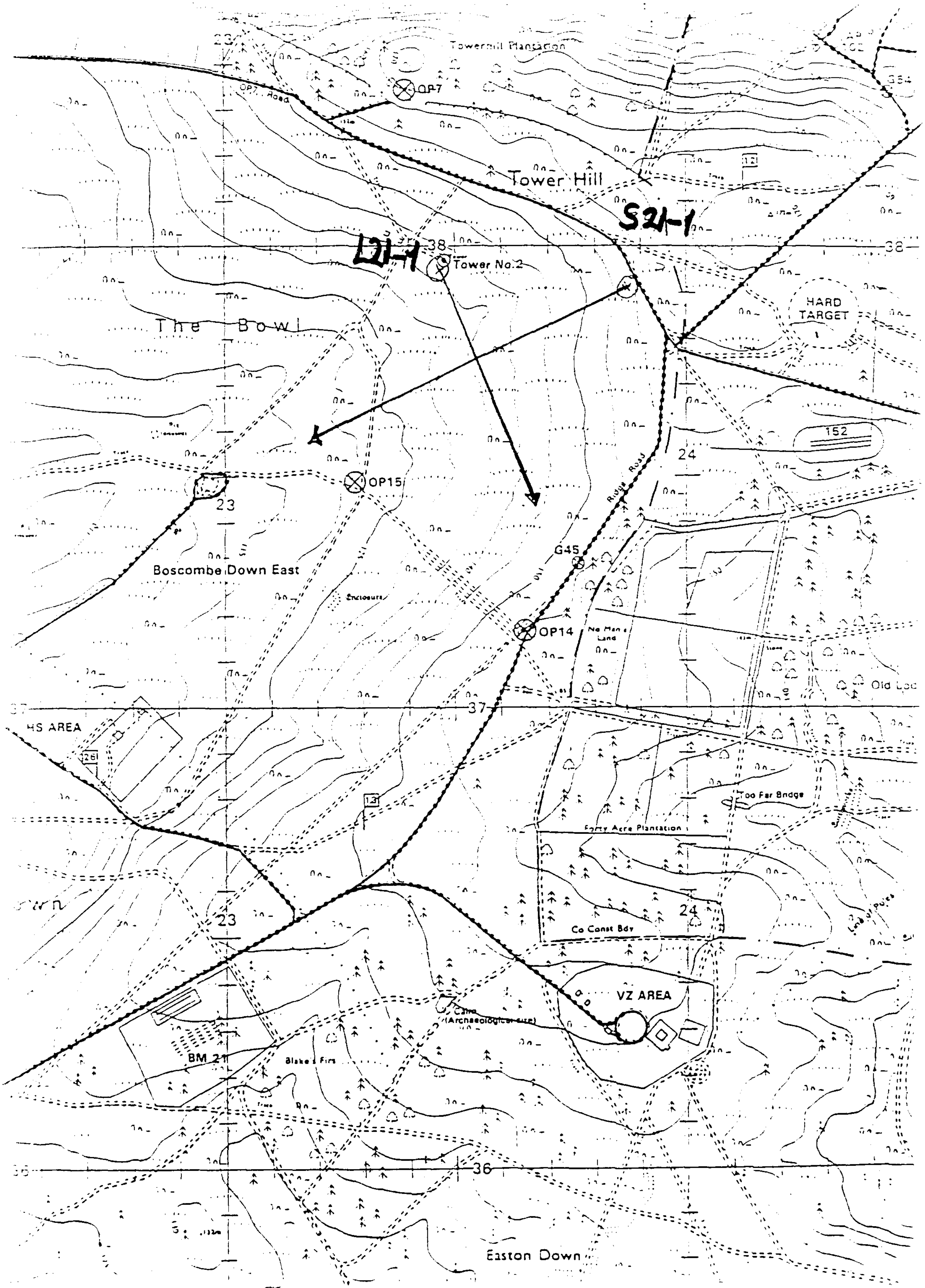
G2
AP105
G44
G43
G43A
C.D.E. Farm
Tower Hill Plantation
OP7
Tower Hi
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
Boscombe Down East
G45
OP14
Cout
G39
37
HS AREA
G50
G38
OP6
L20-1
Idmiston Down
Stop Butt
BM 21
Blake's Firs
Blast Rig
S20-1
OP3
G51
36
Easton Down
Ridge Road
Enclosure
Tumulus



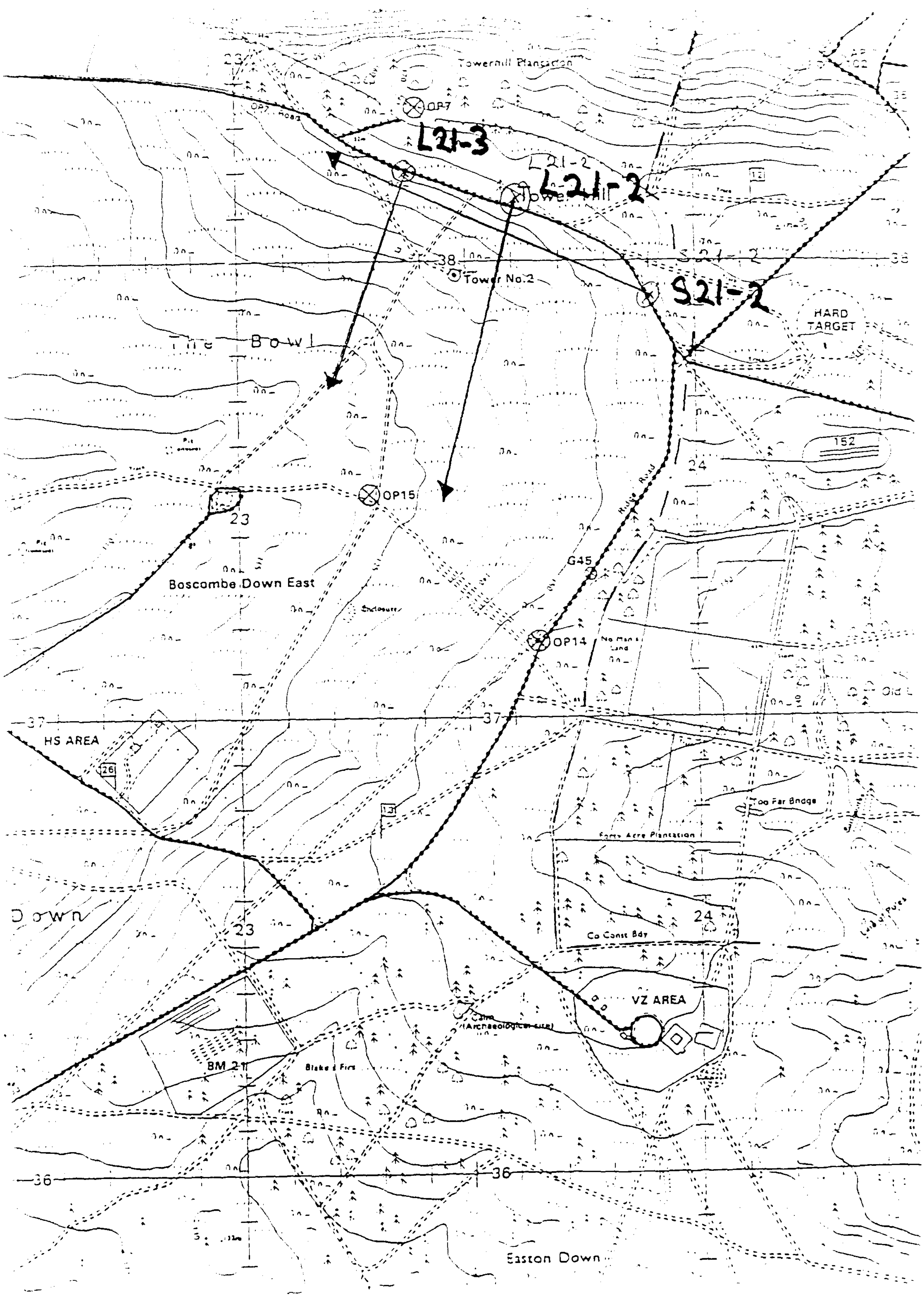
G2
AP105
G44
G43
G43A
Towerhill Plantation
OP7
OP7 Road
Tower Hill
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G49
Boscombe Down East
G45
OP14
G39
Tumulus
37
HS AREA
G50
G38
OP6
L20-2
Idmiston Down
Stop Butt
S20-2
Tumulus
Enclosure
Blast Rig
Ridge Road
BM 21
Blake's Firs
G51
OP2
36
Easton Down



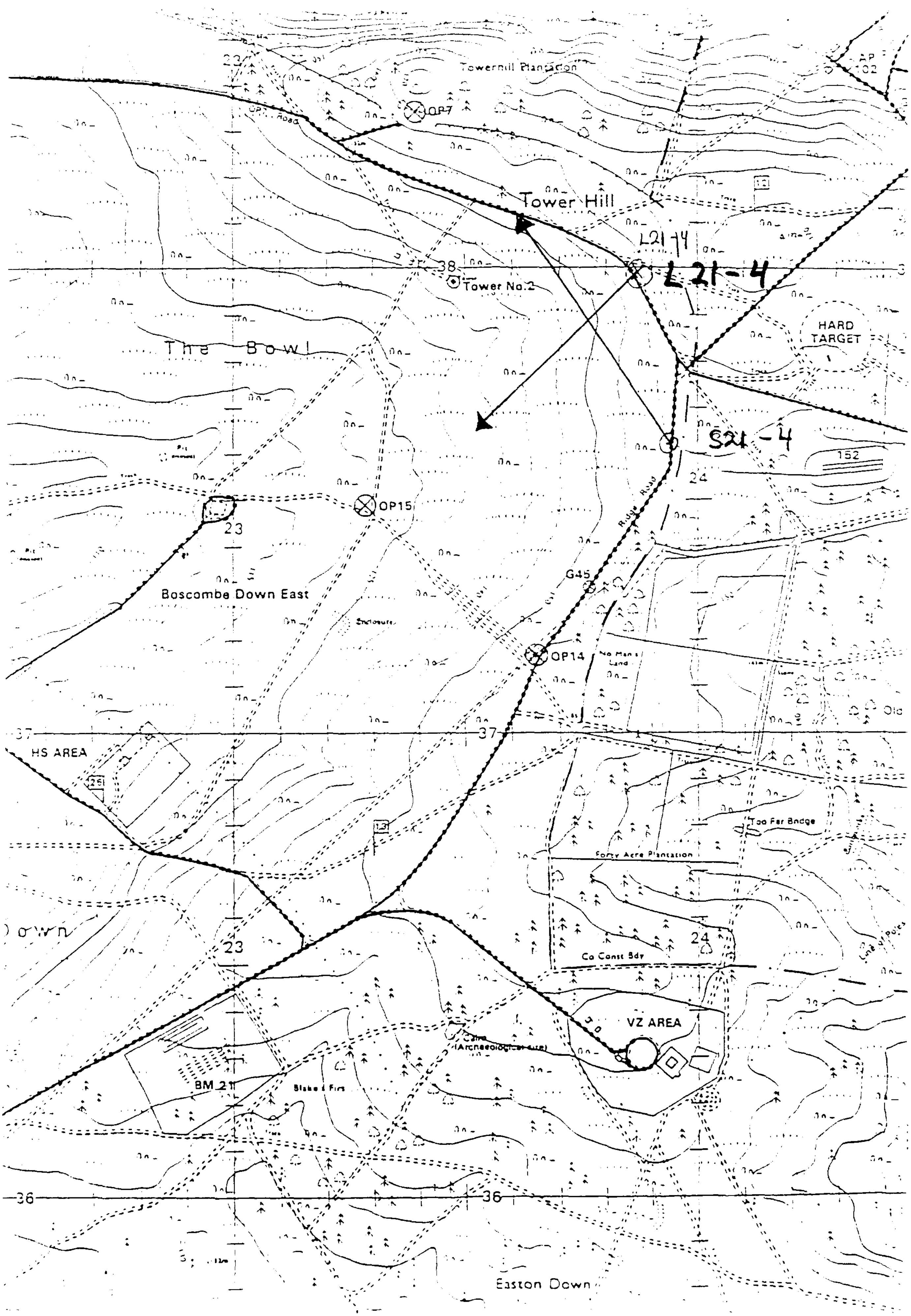
Towerhill Plantation
OP7
OP7 Road
S20-3
Tower Hill
L20-3
Tower No.2
HARD TARGET
The Bowl
OP15
Boscombe Down East
G45
Ridge Road
OP14
No Man's Land
HS AREA
26
13
Too Far Bridge
Forty Acre Plantation
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Easton Down
152
38
37
36
23
24



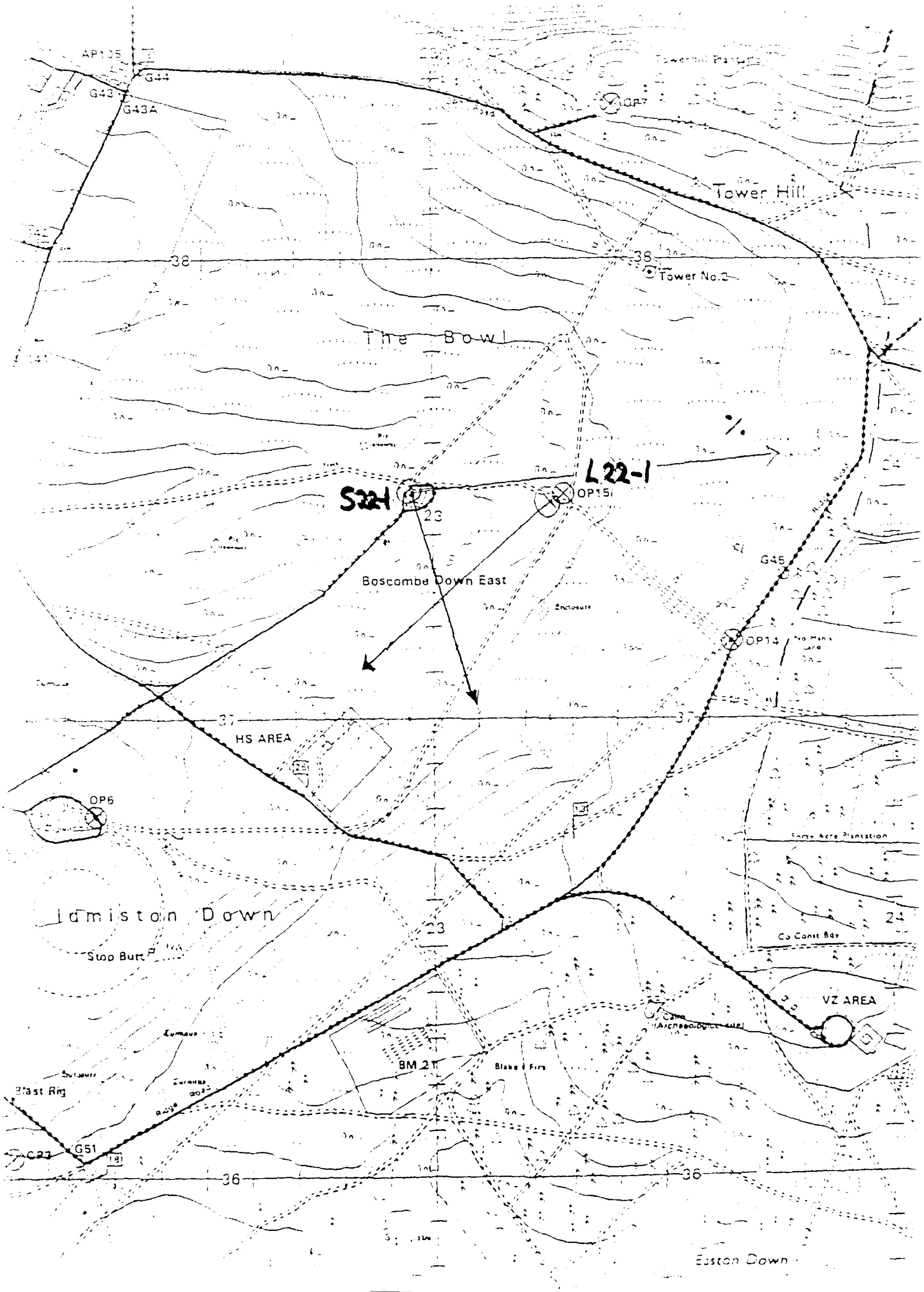
Towerhill Plantation
OP7
OP7 Road
Tower Hill
S21-1
L21-1
Tower No.2
38
The Bowl
HARD TARGET
152
24
OP15
23
Ridge Road
G45
Boscombe Down East
OP14
No Man's Land
Old Lod
37
HS AREA
Too Far Bridge
Forty Acre Plantation
13
24
23
Co Const Bdy
VZ AREA
BM 21
Blake's Firs
36
Easton Down

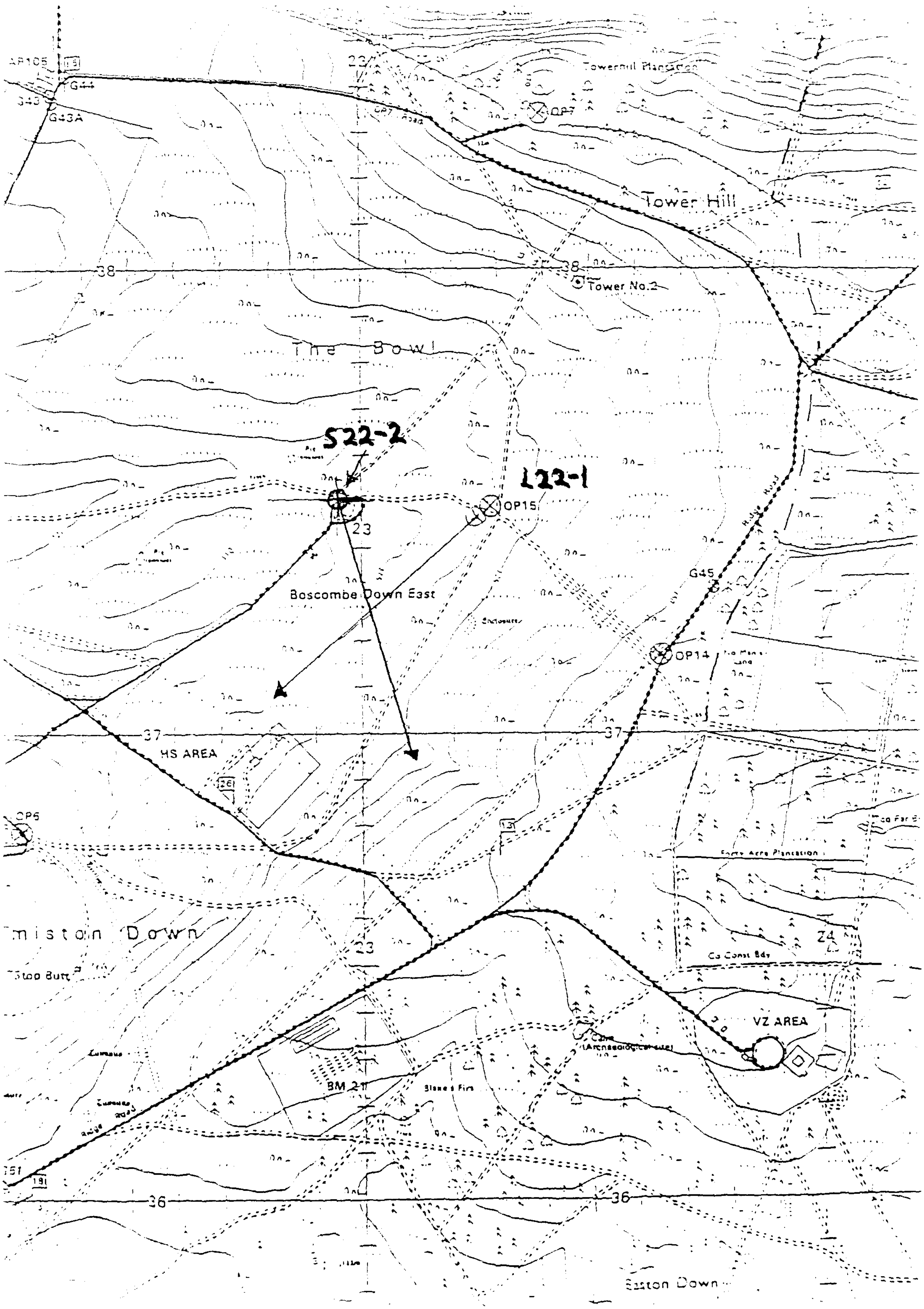


Towerhill Plantation
OP7
L21-3
L21-2
Tower No.2
S21-2
HARD TARGET
38
The Bowl
152
24
OP15
23
Ridge Road
G45
Boscombe Down East
OP14
37
HS AREA
26
13
Too Far Bridge
Forty Acre Plantation
Down
Co Const Bdy
VZ AREA
BM 21
Blake's Firs
36
Easton Down

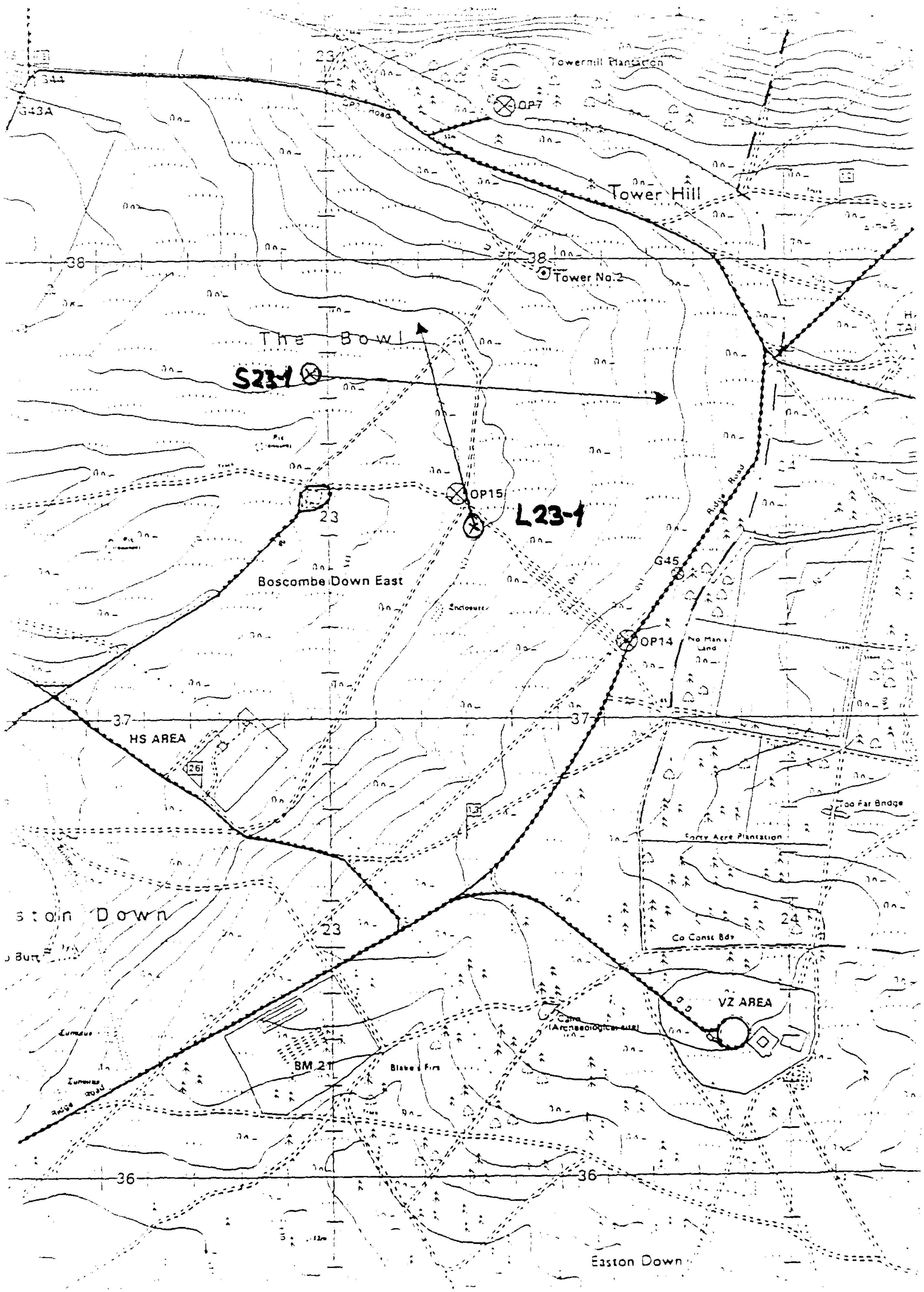


Towerhill Plantation
OP7
Tower Hill
L21-4
Tower No.2
The Bowl
HARD TARGET
S21-4
OP15
Boscombe Down East
G45
OP14
No Man's Land
HS AREA
Too Far Bridge
Forty Acre Plantation
Co Const Bdy
Down
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Easton Down

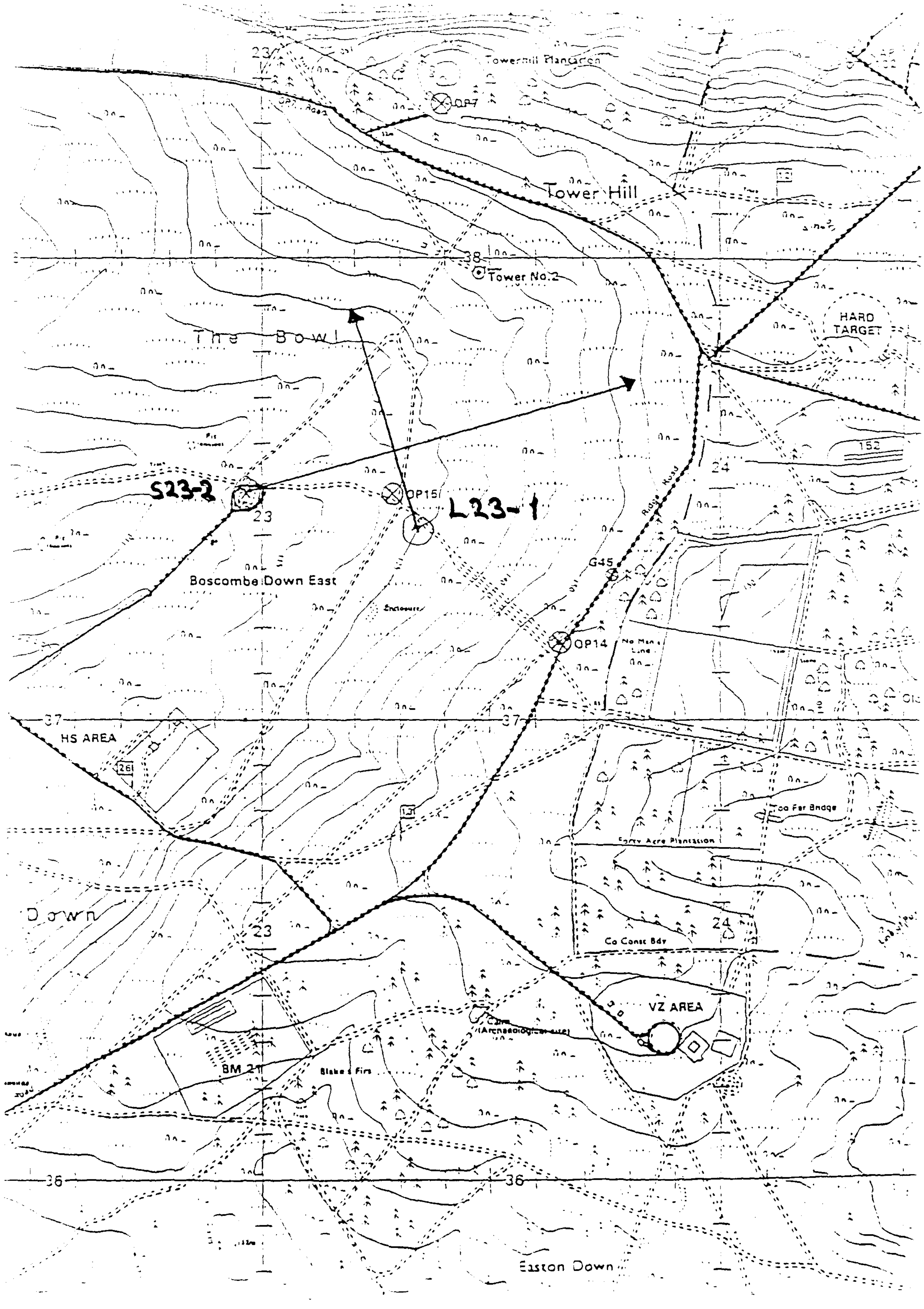

AP135
G44
G43
G43A
Towerhill Parade
OP7
Tower Hill
38
Tower No.2
The Bowl
%
L22-1
S22-1
OP15i
23
24
Boscombe Down East
Enclosure
G45
OP14
No Mans Land
37
HS AREA
OP6
Forty Acre Plantation
Idmiston Down
Co Const Bdy
Stop Butt
VZ AREA
BM 21
Blake's Firs
Blast Rig
G51
C27
36
Easton Down



S22-2
L22-1
Towerhill Plantation
OP7
Tower Hill
Tower No.2
The Bowl
OP15
Boscombe Down East
G45
OP14
HS AREA
OP6
Forty Acre Plantation
Co Const Bdy
VZ AREA
BM 211
Easton Down
G44
G43
G43A
AP105

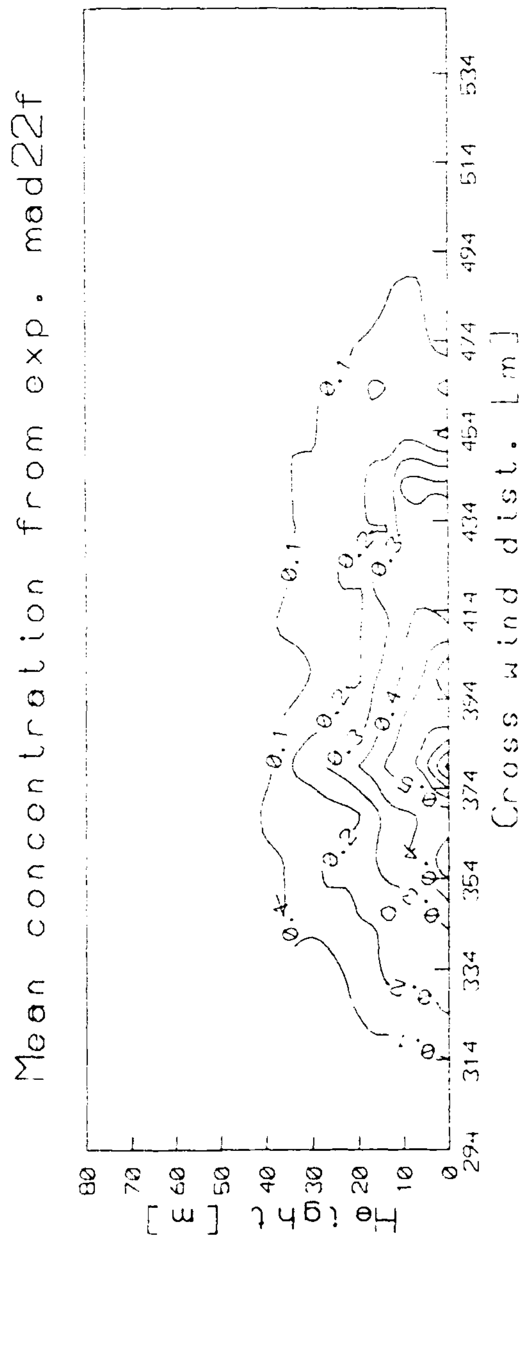


Towerhill Plantation
OP7
G44
G43A
Tower Hill
38
Tower No.2
The Bowl
S23-1
OP15
L23-1
23
Boscombe Down East
G45
OP14
No Man's Land
Ridge Road
37
HS AREA
26
13
Forty Acre Plantation
Too Far Bridge
24
Co Const Bdy
ston Down
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
36
Easton Down



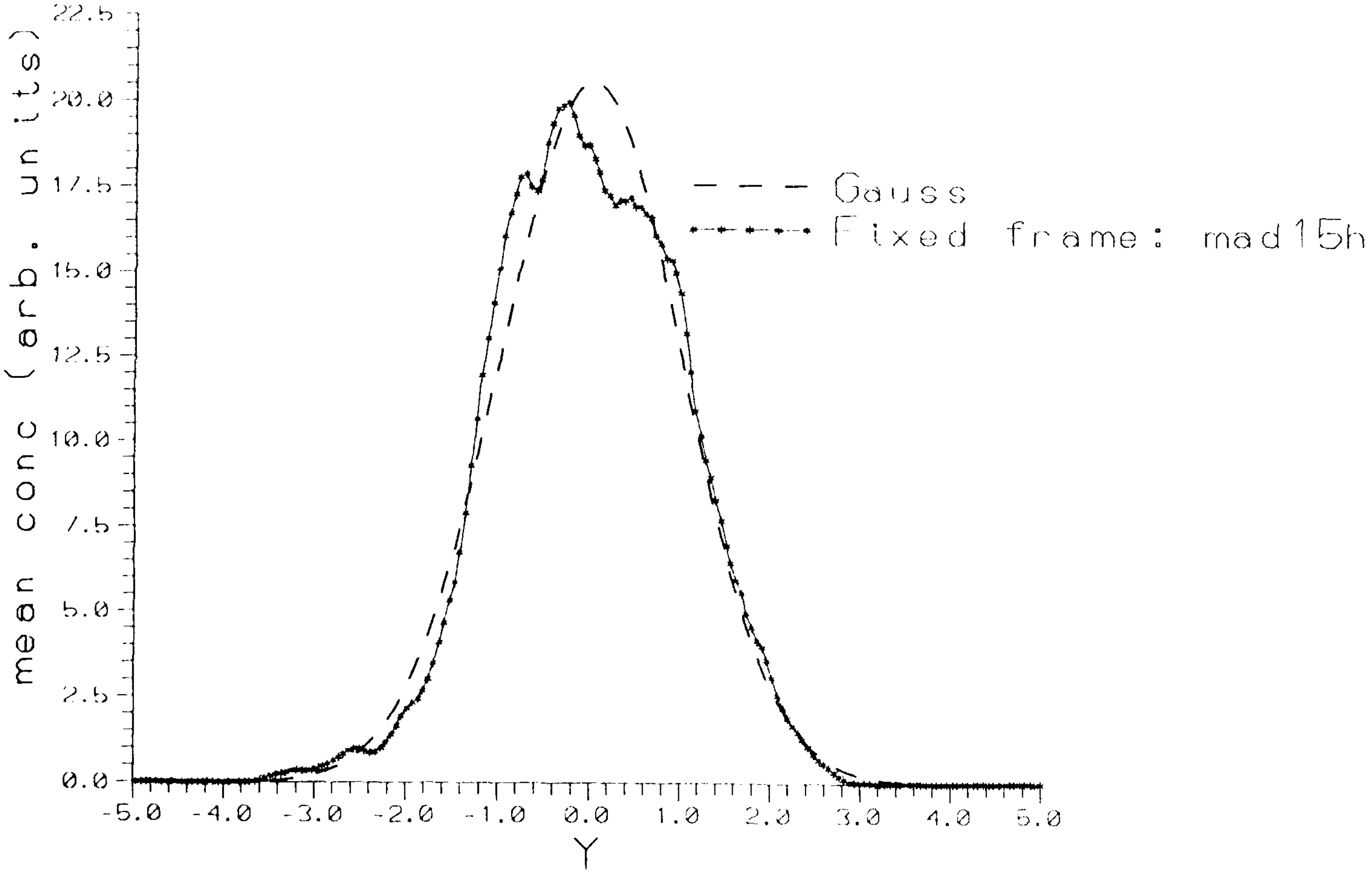
Towerhill Plantation
OP7
Tower Hill
Tower No.2
HARD TARGET
The Bowl
S23-2
OP15
L23-1
Ridge Road
152
24
23
38
37
36
Boscombe Down East
G45
OP14
HS AREA
Down
Forty Acre Plantation
Co Const Bdy
VZ AREA
BM 21
Blake's Firs
Easton Down

FIG. III.1

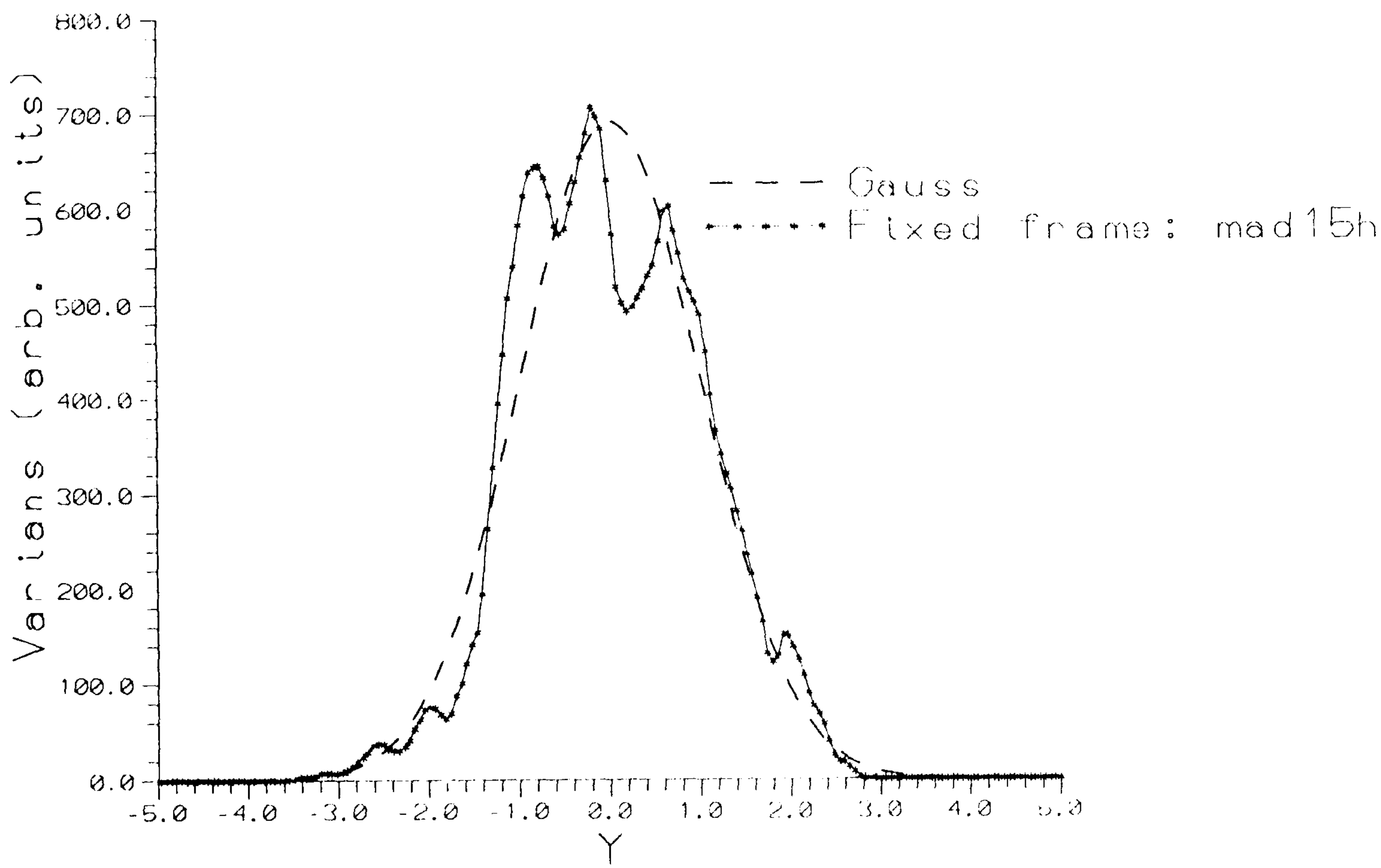


Mean concentration from exp. mad22f
Height [m]
Cross wind dist. [m]
0 10 20 30 40 50 60 70 80
294 314 334 354 374 394 414 434 454 474 494 514 534
0.1
0.2
0.3
0.4

Fig 2a



mean conc (arb. units)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Y
Gauss
Fixed frame: mad15h



Varians (arb. units)
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
Y
Gauss
Fixed frame: mad15h

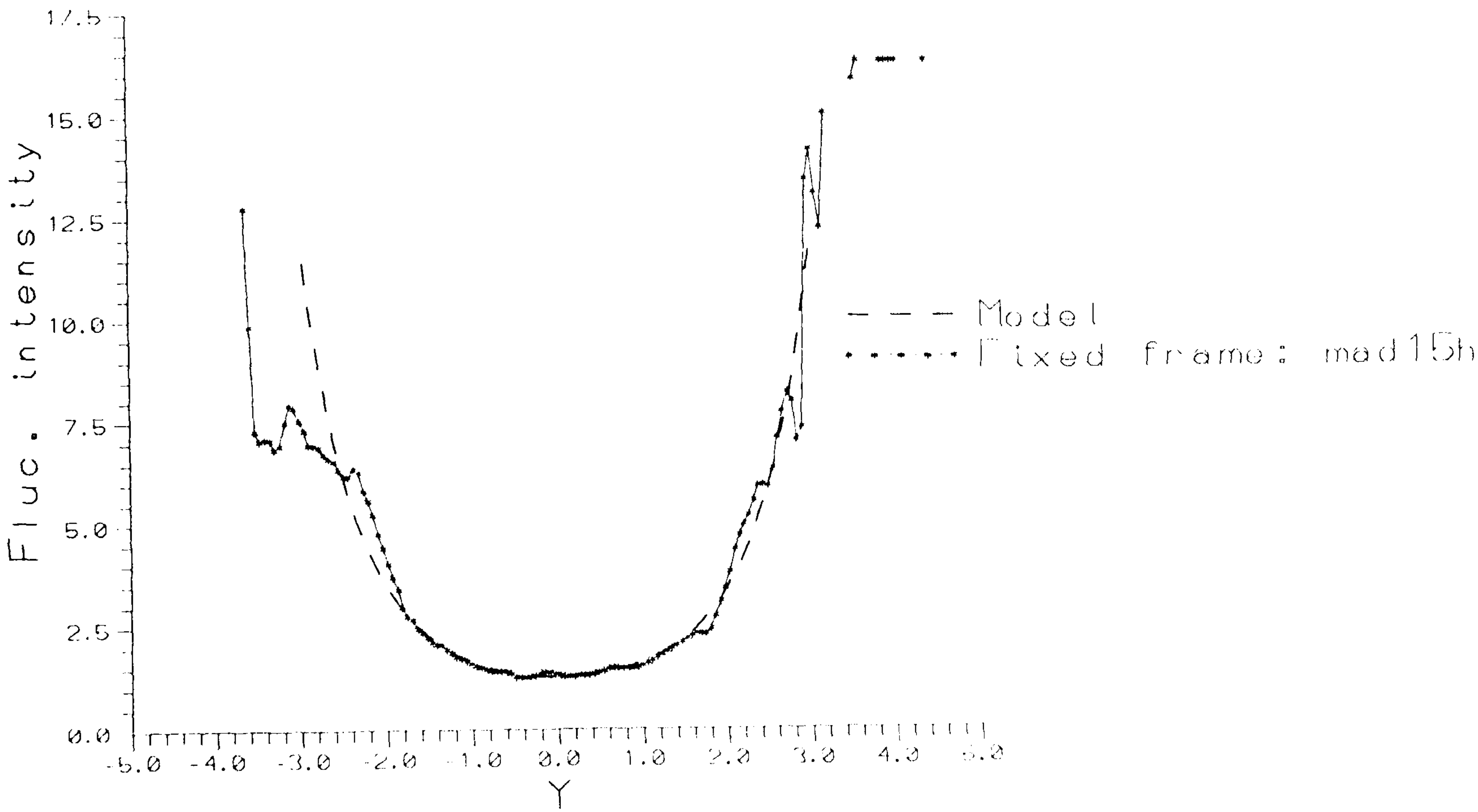
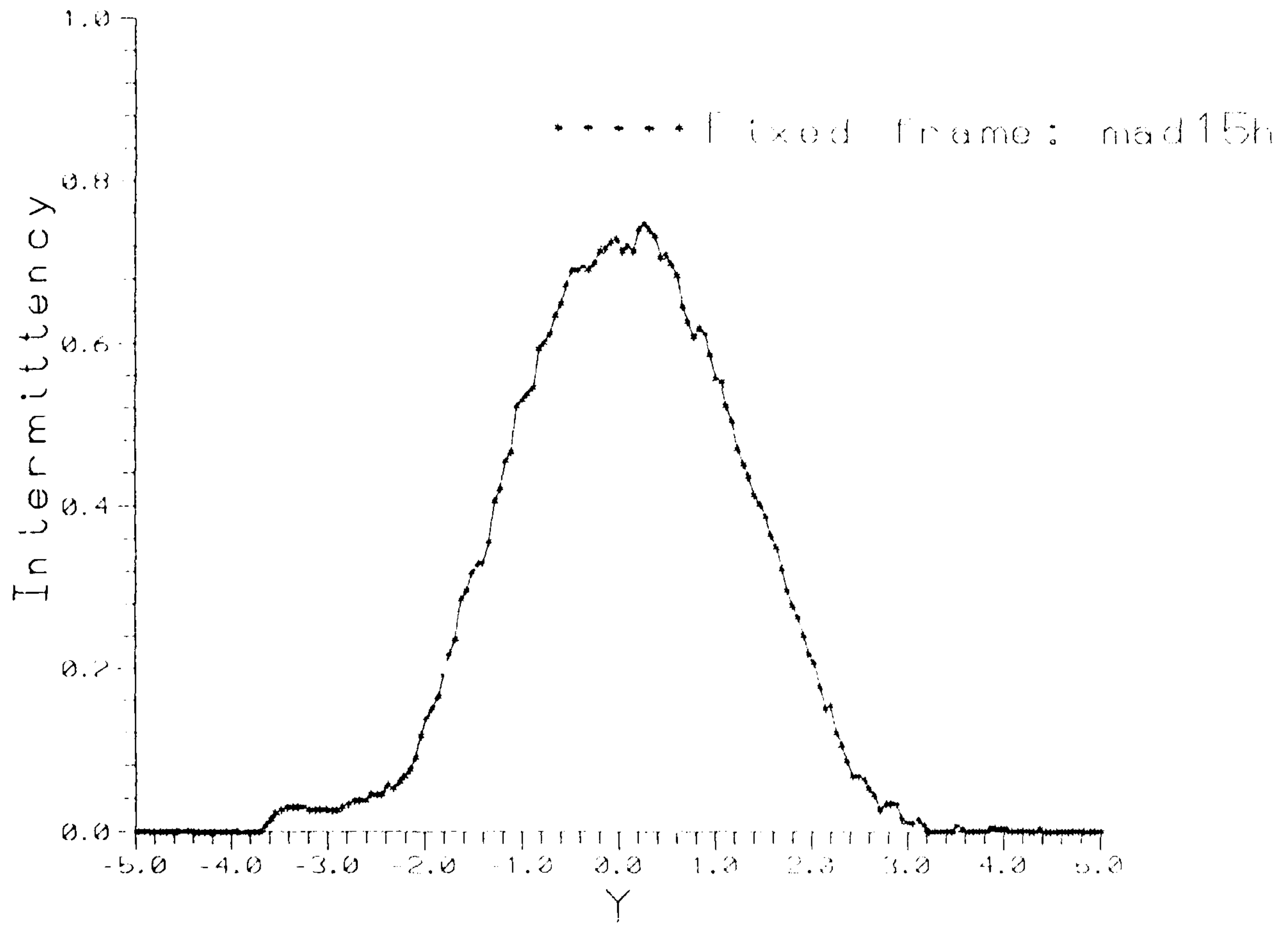
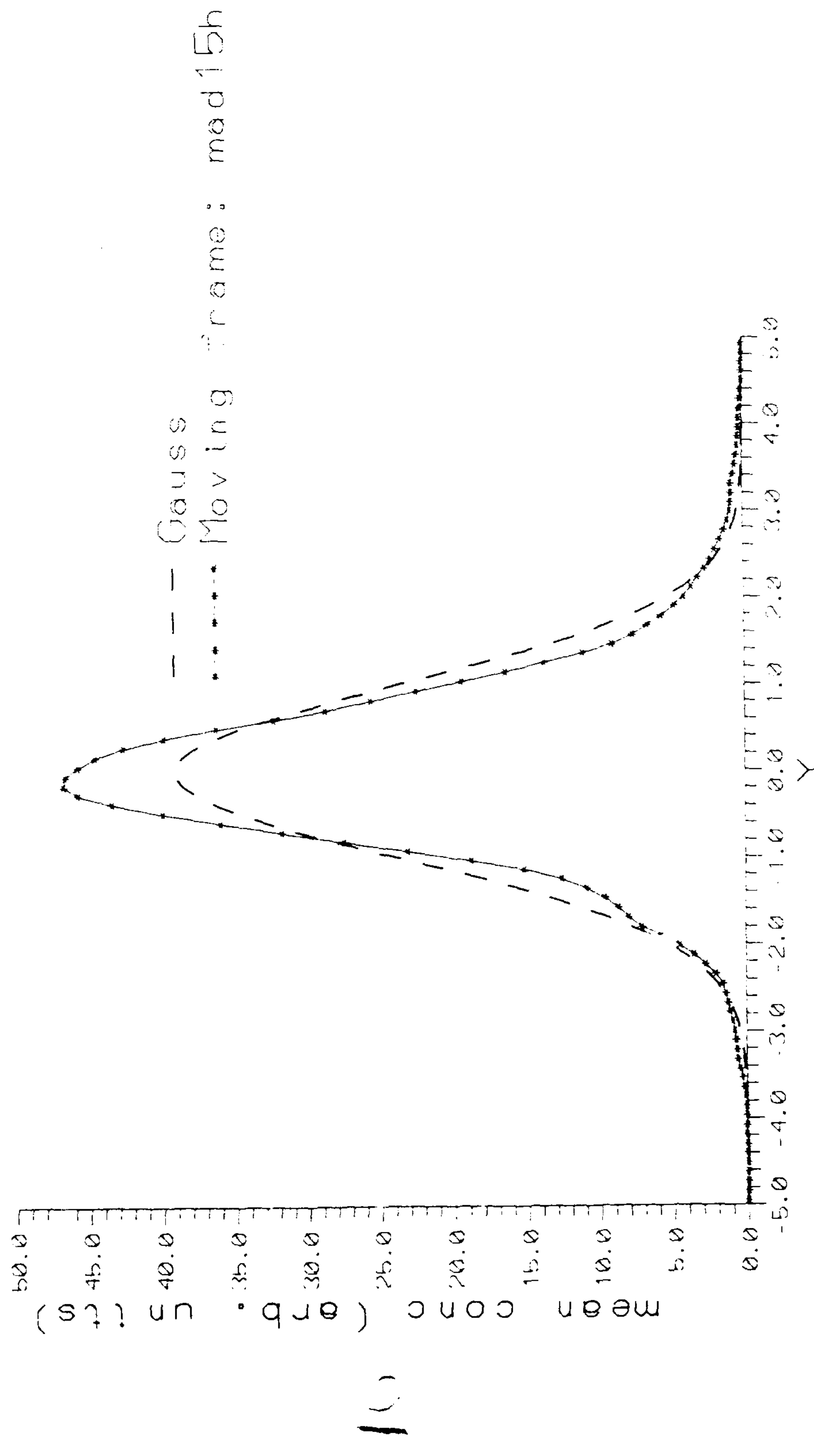

Fluc. intensity
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0
Y
Model
Fixed frame: mad15h

Fig III C

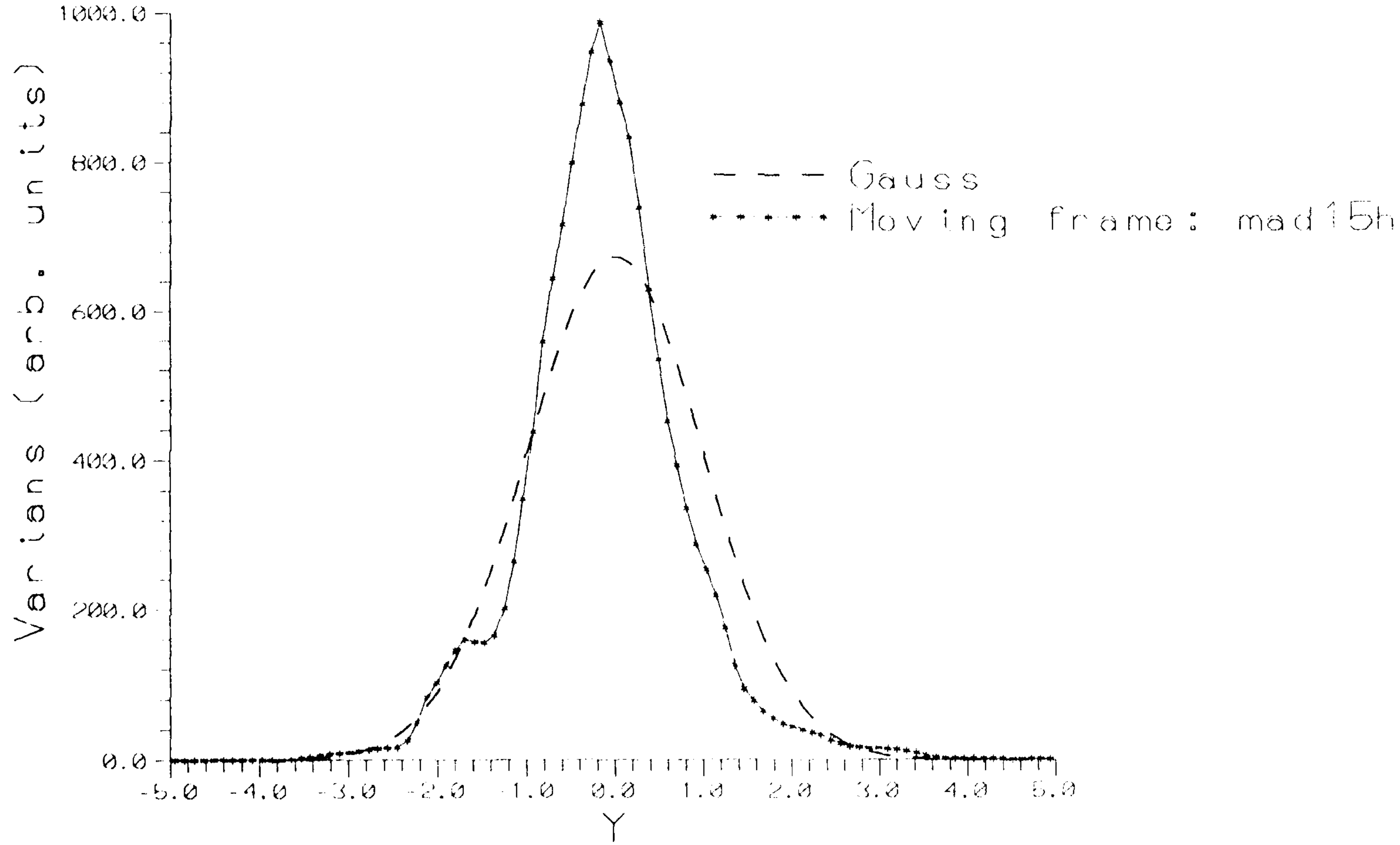


Fixed frame: mad15h
Intermittency
Y
1.0
0.8
0.6
0.4
0.2
0.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

Fi — 3a.

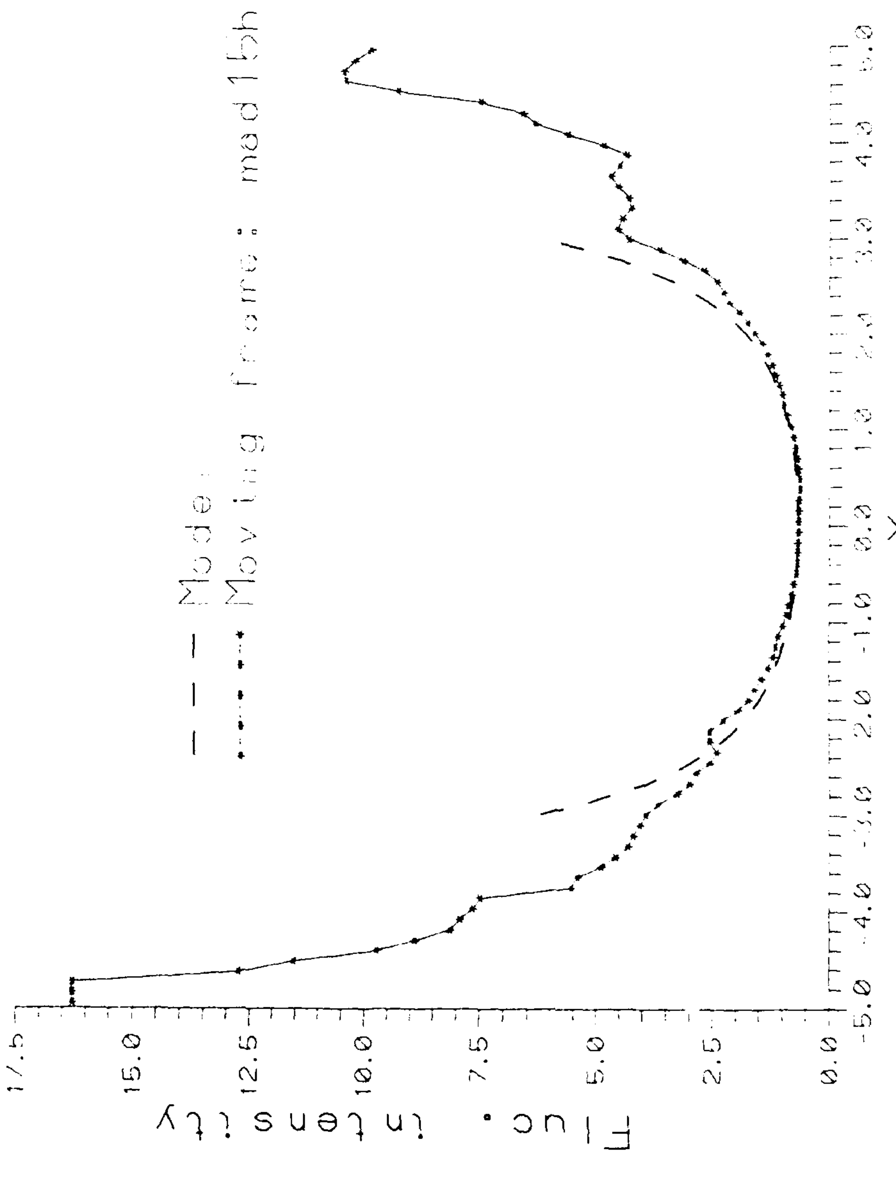


Gauss
Moving frame: mad15h
mean conc (arb. units)
Y
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0



Gauss
Moving frame: mad15h
1000.0
800.0
600.0
400.0
200.0
0.0
Varians (arb. units)
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Y

Fig II 3c



Model
Moving frame: med15h
Fluc. intensity
Y
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

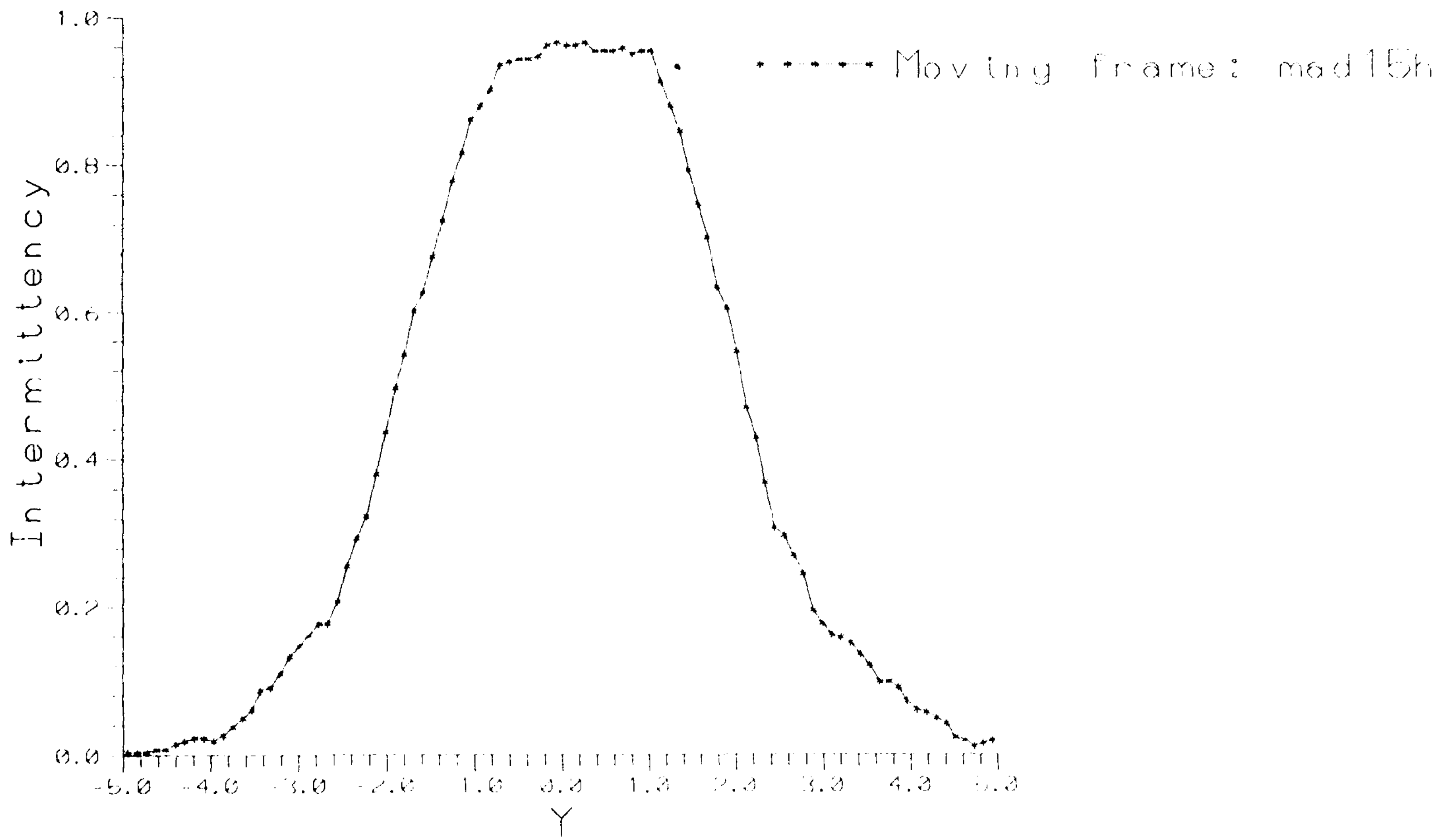
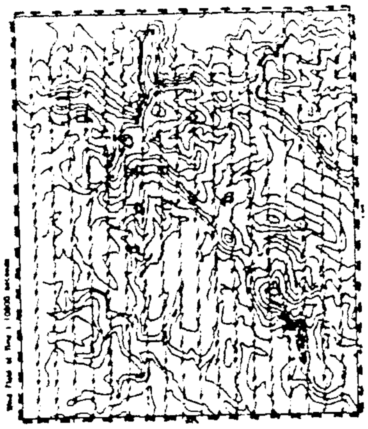
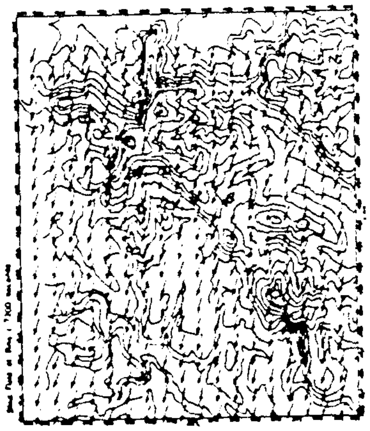

Moving frame: mad15h
Intermittency
Y
1.0
0.8
0.6
0.4
0.2
0.0
-5.0
-4.0
-3.0
-2.0
1.0
0.0
1.0
2.0
3.0
4.0
5.0

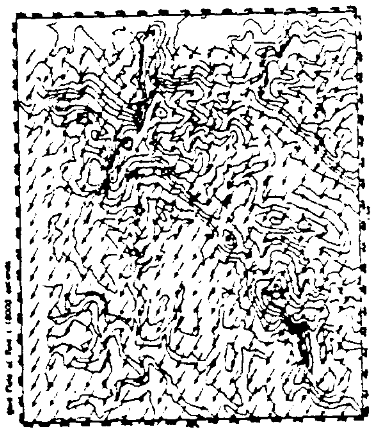
Fig. IV.1

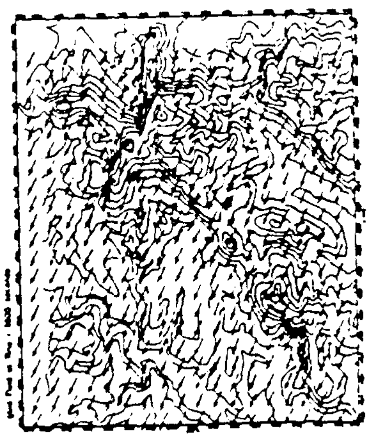


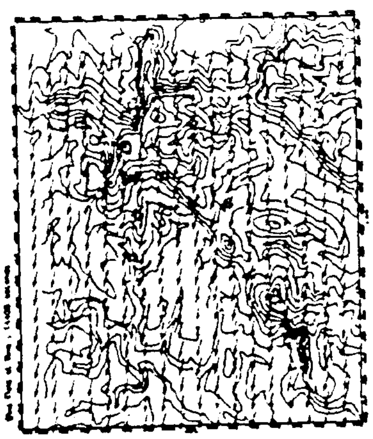
LINCOM Flow MODELLING.

Porton
September 17, 1992
Release Time: 11:10 - 16:10
Hourly fitted Windfields





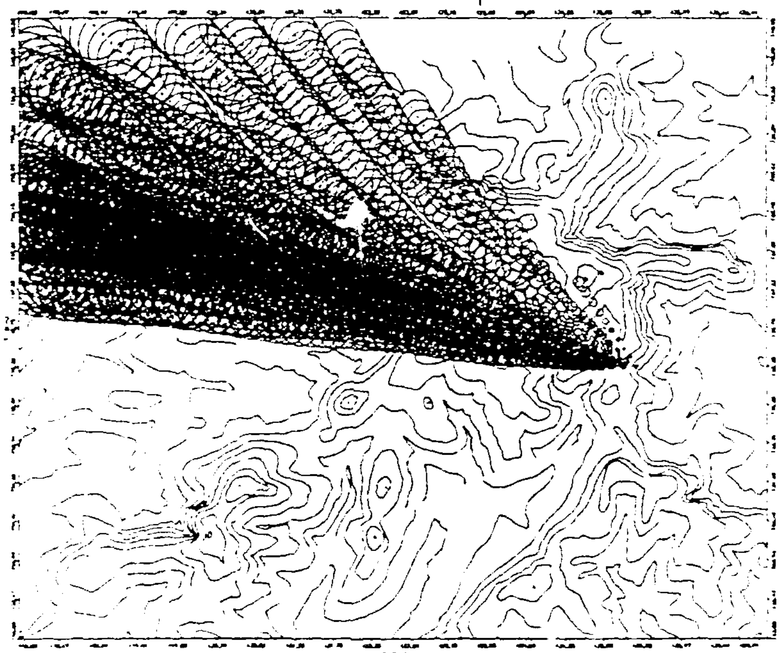




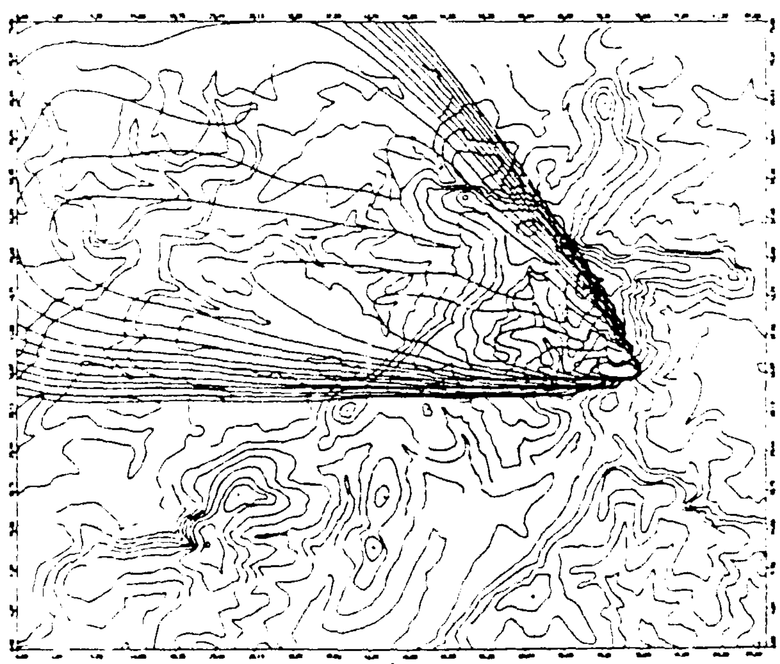
Porton

September 17, 1992
Release Time: 11:10 - 16:10

10 minute series of puffs



5 hour integrated concentrations



0.000 3641.471

Fig. IV.4

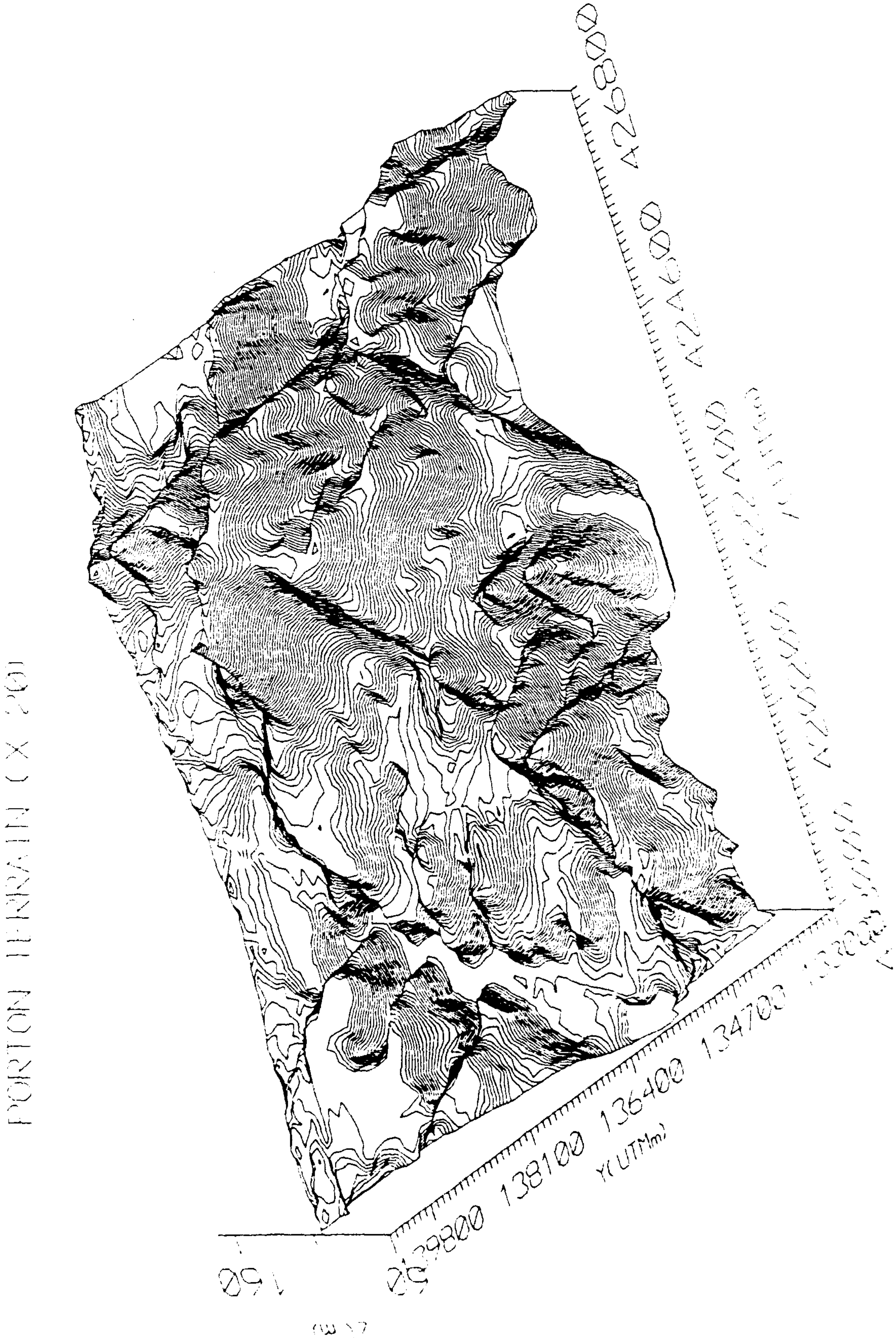
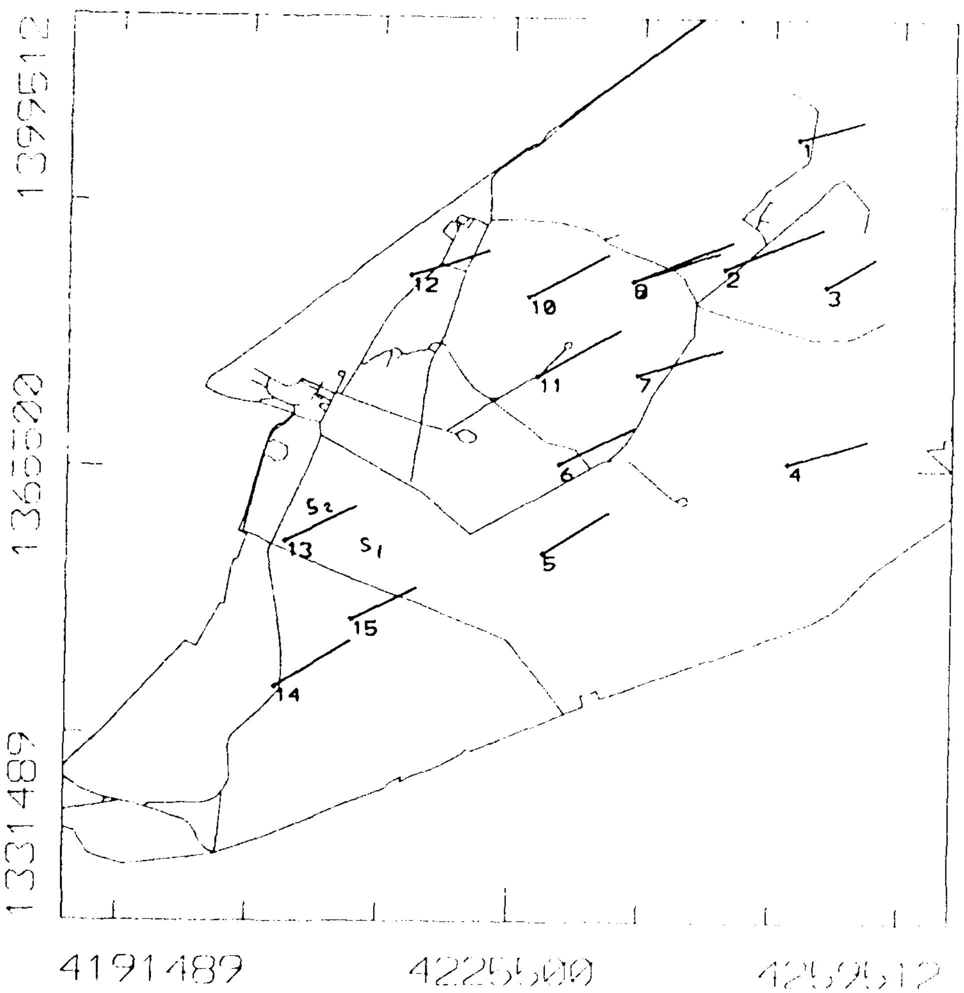

PORTON TERRAIN (X 20)
426800
424600
134700
136400
138100
Y(UTMm)
160

Fig. IV.5



S.Oct'92

Plot: 16/4/1993

Tick distance: 10000

Value factor: 10000.000

Contrast step: 10000.000

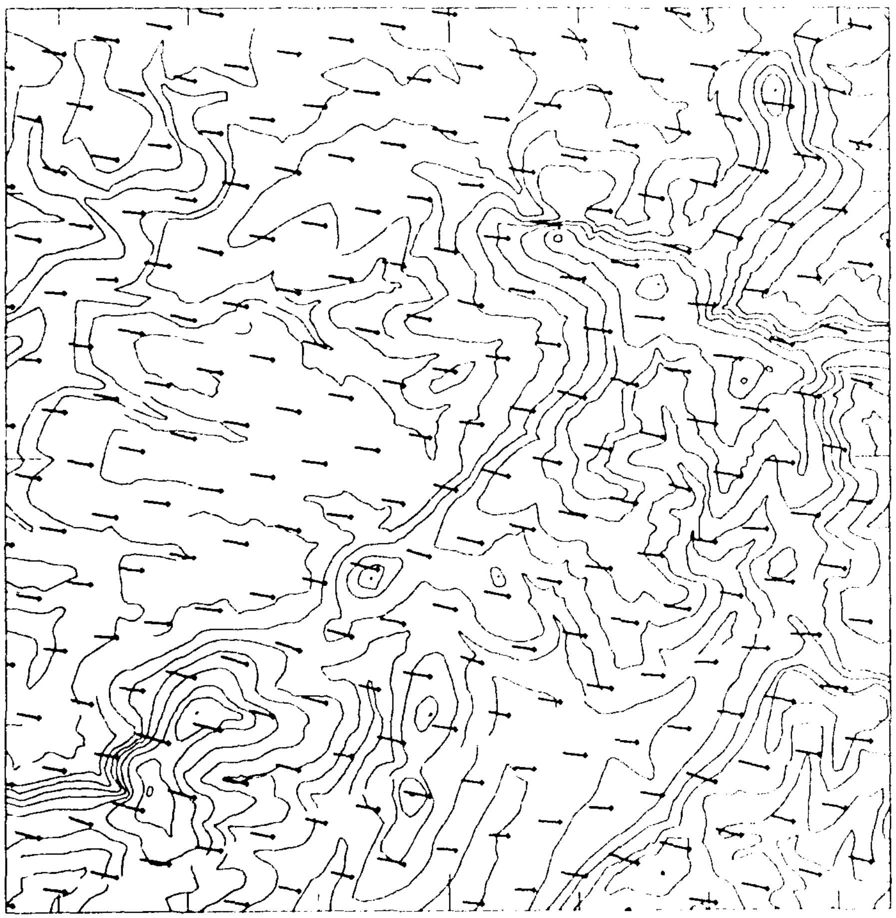
Landscape file: ROADS.BLN

Map file: MASTS.MAP

Data file: 920912.VCT

Record: 1

Time: 12.11:05:00



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BI

Map file: LINCOM.MAP

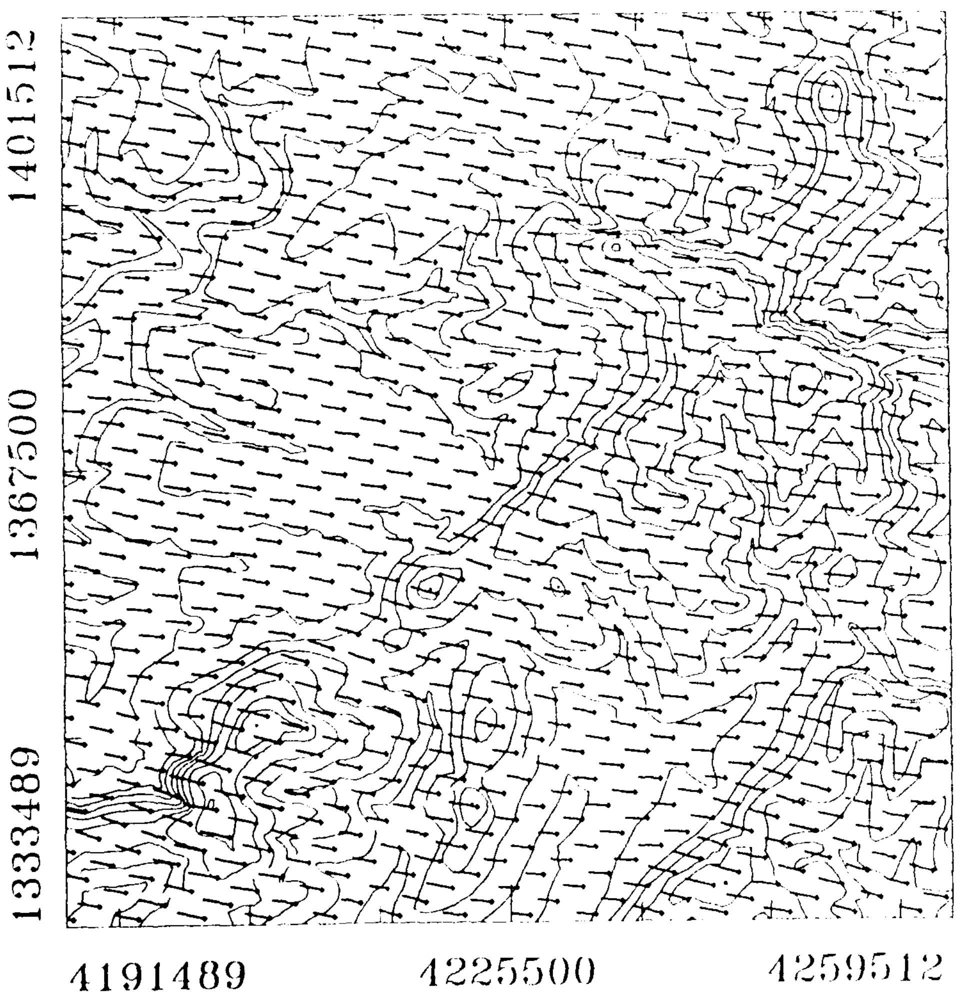
Data file: LINCOM.VCT

Record: 3

Time: 0,00:20:00

Fig IV.6

Fig. IV. 4



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

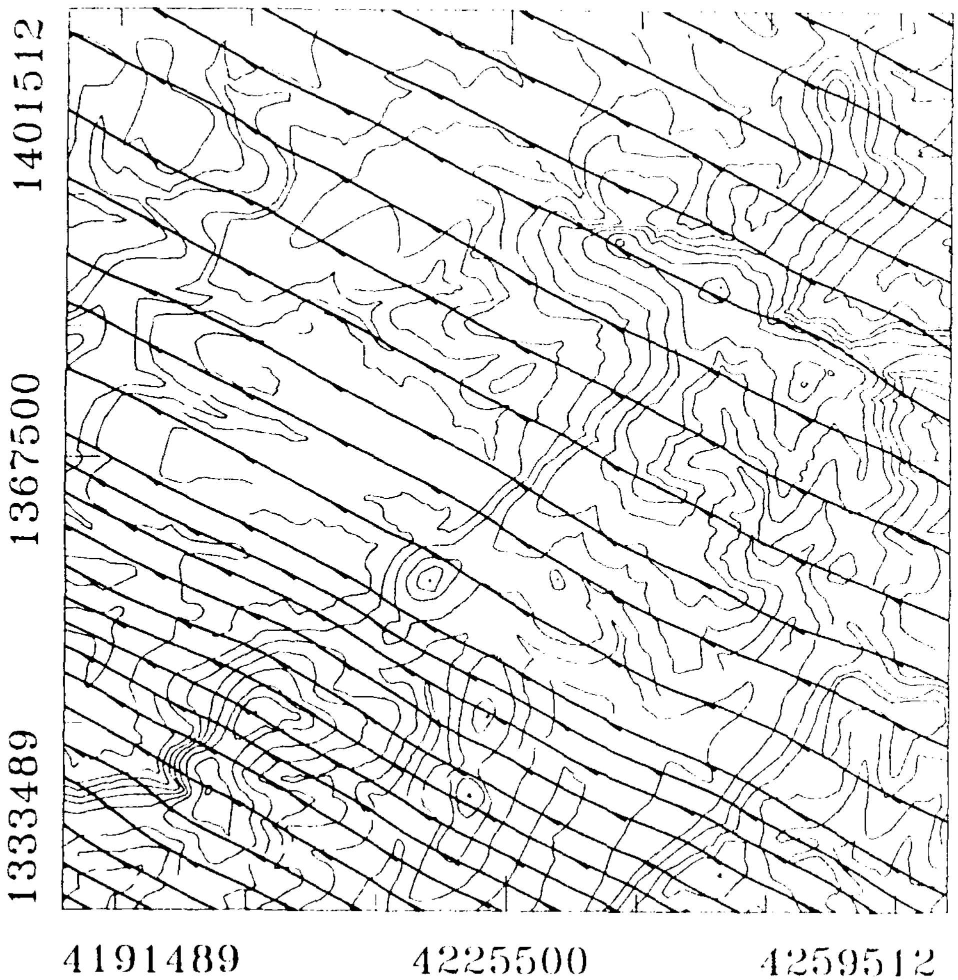
Landscape file: TERRAIN.BLN

Map file: LINCOM.MAP

Data file: LINCOM.VCT

Record: 3

Time: 0,00:20:00



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BL

Map file:

Data file: LINCOM.LNS

Record: 1

Time: 0,00:00:00

Fig. IV.8